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The Adler Planetarium and Astronomical Museum of Chicago*

By PHILIP FOX, *Director*

Over the world there are many museums of art, where are collected masterpieces from the brush, the chisel, the goldsmith's table, the potter's wheel, or the loom,—things which bear witness to man's age-long striving for the expression of beauty, in form or color or texture. Fewer, however, are the museums where one may look for evidence of man's intellectual awakening expressed in the development of his powers of reason; and fewer still, but of growing importance, are the museums of the physical sciences. These museums come as powerful aids to the great libraries, storehouses of learning.

If all persons could be informed of the successive advances of science, if the phenomena and the laws which govern them and which may be derived from orderly consideration of them could be presented in such way as to win general understanding, the progress of learning would be greatly accelerated. It should be the aim of every museum of science to exhibit its material with this end in view. Such attempts in the natural sciences have perhaps been more extensive and perhaps more successful than those in the physical sciences. One sees many interesting and instructive exhibits in numerous museums of Natural History. It is more difficult to prepare in form for easy comprehension exhibits to illustrate the phenomena and laws of those sciences which walk hand in hand with mathematics.

The Adler Planetarium and Astronomical Museum of Chicago, an institution of type quite new to America, opened its doors to the public on 12 May 1930. The institution had been dedicated, and presented to the South Park Commissioners, on the tenth of May in the presence of a distinguished company. On this occasion Mr. Leo Wormser presided as Chairman. In conformity with the practice of the ancient school of Pythagoras who taught music and mathematics together, there was music by the Dasch String Quartette: "Music of the Spheres" Ruben-

*Grateful acknowledgment is made to Dr. K. Bauer of Carl Zeiss Inc. for certain illustrative photographs, to Mr. Henry Simon whose excellent articles in the *American Machinist* in 1929 served to clarify certain mechanical features, to Mr. F. W. Schlesinger for aid in the preparation of diagrams, and to Miss Maude Bennot, Assistant Director, for aid in the preparation of this account, for aid in the formulation of the program and all elements of the administration of the Planetarium and Museum.

stein and "Nocturne, Quartette No. 2" Borodine. The Invocation was delivered by Mr. Horace J. Bridges, the Presentation by Mr. Max Adler, the Acceptance by Mr. Philip Graver, an Address and Demonstration by the Director.

It is natural for one interested in astronomy to inquire how this institution came into being, how it is housed, what may be seen there,

Fig. 1. Dedication Plaque.

what is its purpose, and what response the public has given to its offerings.

Its origin may be found in the development at Jena of the optical planetarium and in the generosity of the donor, Mr. Max Adler of Chicago. Mr. Adler's aim is well expressed in the following quotations from his presentation address:

"Chicago has been striving to create, and in large measure has

succeeded in creating, facilities for its citizens of today to live a life richer and more full of meaning than was available for the citizens of yesterday. Toward the creation of such opportunities I have desired to contribute.

"The popular conception of the universe is too meager; the planets and the stars are too far removed from general knowledge. In our reflections, we dwell too little upon the concept that the world and all

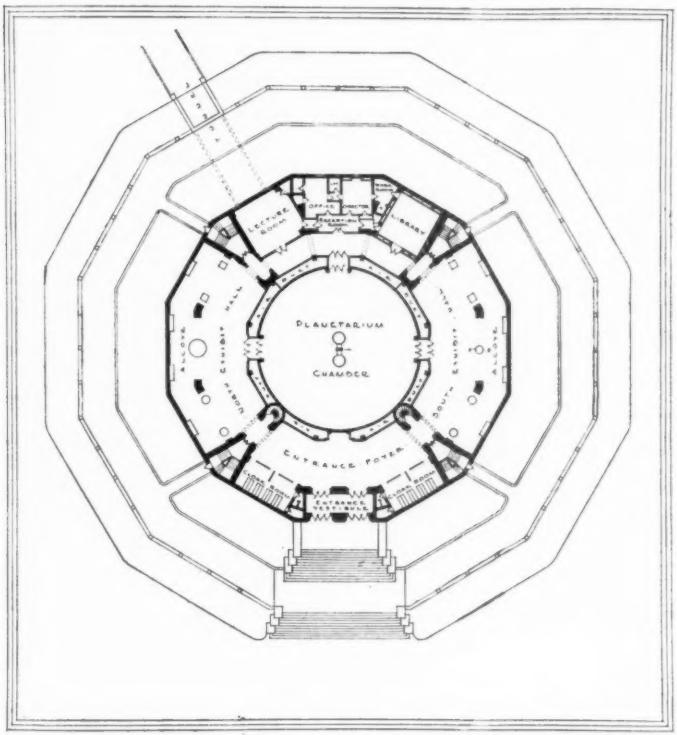


FIG. 2. PLAN OF THE BUILDING SHOWING LOCATION OF THE PLANETARIUM CHAMBER, AND THE SURROUNDING MUSEUM CORRIDORS, OFFICES, AND ENTRANCE FOYER.

human endeavor within it are governed by established order and too infrequently upon the truth that under the heavens everything is interrelated, even as each of us to the other."

And again, "The planetarium has been the subject of praise by scientists and educators. One of them has characterized it as 'a schoolroom under the vault of heaven' and as 'a drama with the celestial bodies as actors'.

"It is my hope that the youth of our city, and indeed of other cities, may through this dramatization find new interests and fresh inspiration and also that with the aid of the Planetarium and Astronomical Museum, science may be advanced."

Though this Chicago institution bears a double name and is commonly referred to as the Planetarium, it is in reality an Astronomical Museum of which the Planetarium instrument is the principal exhibit.

It stands on an island in Lake Michigan to the east of those neighboring institutions, the Field Museum of Natural History and the Shedd Aquarium. The three are fittingly closely associated and form a trinity dedicated to the study of "The Heavens above, the Earth beneath, and the waters under the Earth."

The building is an imposing edifice of rainbow granite with copper dome. The plan (Fig. 2) shows that its shape is a regular dodecagon. The exterior diameter is 160 feet. Inset at the exterior corners are bronze plaques of the twelve Signs of the Zodiac by the sculptor, Alfonso Iannelli. Those for Leo and the Gemini have been selected as

representative. Usually, when figures of the Zodiacal Signs are used for exterior decoration they are arranged as on a celestial globe, as though the sky were projected upon the surface, in which case they would be placed successively in counter-clockwise order. The sculptor had, however, nearly finished his modelling with the figures reversed, as on the usual map, before the astronomical director saw the plaques. It was therefore necessary to mount them in clockwise sequence, a permissible arrangement if they are regarded as maps held aloft to match the sky. The stars are placed on the sculptured figures in positions fitting the descriptions of Ptolemy, or perhaps it were better to say that the figures were designed to fit the requirement of the fixed framework of stars.

Centrally located within the building is the circular planetarium chamber 72 feet in diameter, carrying a hemispherical dome of 68 feet diameter. This is the diameter recommended by the makers of the

instrument. With a larger dome, the stars lose brilliancy and if much smaller, the illusion of the open sky is lost. The linen of the dome is stretched over horizontal battens circling the dome like almucantars. The whole is suspended by metal straps from the outer dome (see Fig. 3). The outer dome has a diameter of eighty feet and is non-concentric with the linen surface. This arrangement results in favorable acoustics unless the speaker stands too near the center of the chamber.

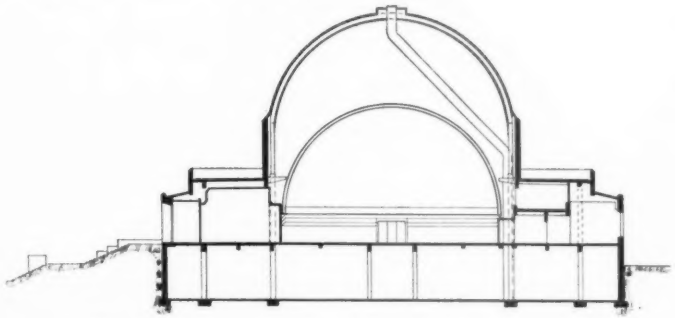


FIG. 3. CROSS-SECTION OF THE BUILDING IN ELEVATION.

About the central hall are the entrance foyer, the museum corridors, offices, library, and auxiliary lecture room. The entrance faces to the west; the offices look to the east on Lake Michigan. Over the offices there is a room for bookstacks and instruments. Below the offices are the heating and ventilating installations, instrument shop and photographic dark room. Below the foyer are the rest rooms. The remainder of the lower floor is being developed as an extension to the Museum. There is a broad upper promenade deck for view of the sky. Portable instruments are carried there on clear evenings. The coelostat for throwing the solar image into the museum chamber below is also on this deck.

The building is regarded as of such merit that for its design the architect, Ernest A. Grunsfeld, Jr., was awarded the 1930 gold medal of the Chicago Chapter of the American Institute of Architects.

Probably the first natural phenomenon to impress itself on man as he began to observe and reason was the orderly succession of day and night. And while he was grateful to the Sun for its light and warmth and the protection and comfort which it afforded, he marvelled no more concerning the Sun than he did about the stars wheeling in the night sky.

> "Thinketh he dwelleth i' the cold o' the Moon
> Thinketh he made it and the Sun to match
> But not the stars, The stars came otherwise."

He saw the Moon and traced her course among the stars in recurrent

phases and saw the brighter planets threading their complex ways. It was long before he was able to unify these phenomena into an harmonious scheme of action, in fact, not until Ptolemy (100-170 A.D.) made his Earth-centered hypothesis with its complex system of epicycles. This hypothesis yielded reluctantly to the Sun-centered theory of Copernicus (1473-1543).

After the announcement of these theories, ingenious men began to make models to represent by means of globes suitably geared together, the observed or calculated motions of the planets and Moon and later also of the other satellites. Not the first, for it is stated that such models date back to Archimedes, but among the earlier of them is that of Christian Huygens constructed in 1682 by the horologist Johannes van Ceulen de la Haye. This may still be seen at the Observatory of Leiden. It is of interest to know that in the calculations for the gearing Huygens came to the invention of continued fractions. These instruments were developed until they became very serviceable in illustrating the phenomena of day and night, of the seasons, of lunar phases, eclipses, transits, occultations, all planetary configurations.

At a date between 1700 and 1710 George Graham, inventor of the compensated pendulum, constructed for Prince Eugene an instrument to show most of the above phenomena. John Rowley copied this instrument with some additions and improvements for the Earl of Orrery. In this lies the origin of the name "orrery" as applied to later elaborate mechanical planetaria. Such instruments varying in size and complexity are to be found widespread. A very interesting one is that made by Eise Eisinga at Franeker, Holland, between 1773 and 1780. In America those of David Rittenhouse, begun in 1767, are worthy of mention: one is at present preserved in Philadelphia. The Rittenhouse planetarium is described in the first volume of the *Publications of the American Philosophical Society*. Perhaps also should be mentioned an American orrery of T. H. Barlow made in 1851, exhibited at Paris in 1867, and now at Transylvania College, Lexington, Kentucky. In some form these mechanical models are common adjuncts to class-room instruction.

In 1912 Dr. Wallace W. Atwood, then Director of the Museum of the Chicago Academy of Sciences, designed a very different instrument which has been called the Atwood Celestial Globe. It is described in the *Bulletin of the Academy*, Vol. 4, No. 2, May, 1913. The essential feature is a globe fifteen feet in diameter. Holes of proper size and location are perforated in the sphere to represent the stars. Light thrown on the exterior of the globe shining through the holes, gives the appearance of the starlit sky to the observers standing within. The southern circumpolar region is cut away and from this section the observers enter the globe to stand on a platform inserted through the same opening. The globe may be rotated about the polar axis to reproduce the diurnal motion. This Atwood Globe which has been in daily use since 1913 is

the progenitor of the new Zeiss Optical Projector. It differs radically from the mechanical planetaria for it is concerned with the appearances of the sky and in no sense is it a mechanical model to explain these appearances.

The Atwood Globe, however, had a much earlier forerunner, for in 1758 Roger Long, Lowndes's Professor of Astronomy at Cambridge, constructed "an enormous astronomical machine . . . at Pembroke College. It is a hollow sphere, about eighteen feet in diameter, with the polar axis parallel to the mundane axis, upon which it is readily turned by a winch and rack-work; thus it can be made to rotate, while about thirty persons conveniently attend a scientific lecture in the interior and contemplate the orderly march of the constellations painted on the moving concavity above them, the stars being pierced through the metal according to the several magnitudes, so that the light penetrates and each assumes a curious radiated or rather stellated form."*

Professor Max Wolf of Heidelberg had something of this sort in mind in his original suggestion to Dr. Oscar von Miller of the Deutsches Museum at München. Von Miller daring to bring the heavens indoors, turned to the firm of Carl Zeiss, Jena, for the execution of the work. The engineers of Carl Zeiss at first worked on the idea of a great rotating perforated globe. "Much experimental construction work was carried out in Jena . . . but no satisfactory solution . . . to create the illusion of the mysterious, silent march of the worlds of Nature . . . was found." It is not surprising that an engineer, Dr. W. Bauersfeld, of this firm, which since its foundation in 1846 has been a leader in the development of optical apparatus, should have evolved the following proposition: "The great sphere shall be fixed, its inner white surface shall serve as the projection surface for many small projectors which shall be placed in the center of the sphere. The reciprocal positions and motions of the little projectors shall be interconnected by suitable driving gears in such manner that the little images of the heavenly bodies, thrown upon the fixed hemisphere, shall represent the stars visible to the naked eye, in position and in motion, just as we are accustomed to see them in the natural clear sky." It took Dr. Bauersfeld and his staff of collaborators and workmen a full five years to demonstrate the practicability of the proposition. No instrument was ever invented more versatile than it for exhibiting the phenomena of a given science. Its success is convincing, even inspiring. It fittingly occupies the central place in the Astronomical Museum of Chicago.

The Optical Planetarium

In its essential elements the optical planetarium (Plate IV) is a composite stereopticon with many projectors throwing images on the interior surface of a great hemispherical dome. It is a very complex

*Cycle of Celestial Objects, Smyth & Chambers, Oxford 1881, pp. 208-9.

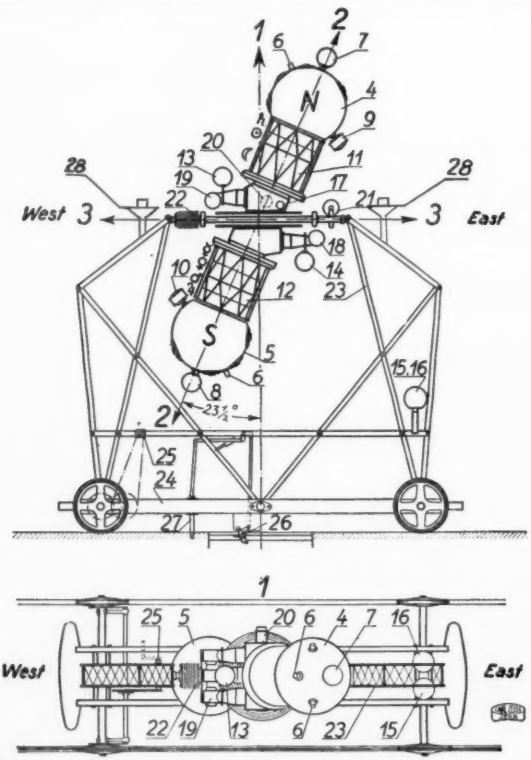
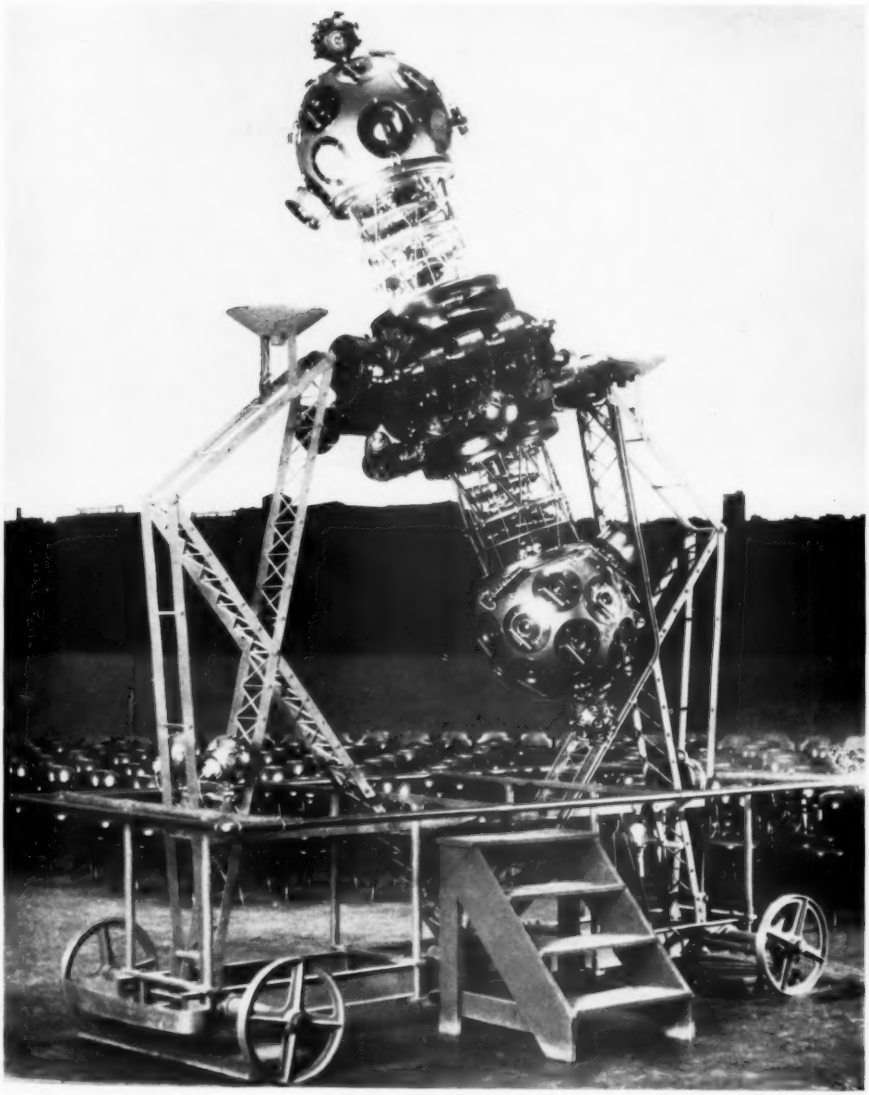


FIG. 4. DIAGRAM OF THE PLANETARIUM INSTRUMENT IN PLAN AND ELEVATION.

1-1—Polar Axis. 2-2—Axis of the ecliptic. 3-3—Horizontal axis extending east and west. The whole projection apparatus may be rotated about this axis, producing the changing aspect of the sky consequent on change of latitude. N, S—Two globes, star projector carriers, on which the 32 projectors for the stars are mounted (4, 5, etc.) N primarily for the northern sky, S for the southern. 6, 6—Projectors for the Magellanic Clouds, Sirius, and typical variable stars. 7, 8—Globes which carry 30 projectors for constellation names. 9, 10—Drum projectors for the Milky Way. 11—Cylindrical frame section containing movable projectors for Saturn, Sun, Moon, Gegenschein, and Zodiacal Light. 12—Cylindrical frame section for Mercury, Venus, Mars, and Jupiter. 13, 14—Two globes, each carrying six projectors to throw the equator, ecliptic, sections of numbered hour circles, and arrows to indicate the poles of rotation. 15, 16—Two globes each carrying two projectors to throw the meridian in the sky. 17—Projector to designate the year. 18—Two motors to drive the instrument about the axis (1-1) for diurnal motion. Used singly they give a day in $1^m\ 4^s$ or $3^m\ 12^s$. 19—Three motors for the annual motion, or more properly speaking the motion of the Sun, Moon, and Planets among the stars. Singly the motors give the year in $5^s.8$, 61^s, and $3^m\ 3^s$. 20—Motor to drive the instrument about axis (2-2) to produce the precessional motion, the 25,800-year precessional cycle in $1^m\ 16^s$. 21—Motor to rotate the instrument about the axis (3-3) for change of terrestrial latitude, period $5^m\ 8^s$. 22—Commutators to transfer circuits from the fixed frame to the movable parts. 23—Fixed frame or pedestal built of thin, steel bars, care being taken to obstruct as little light as possible. 24—The carriage. The whole instrument can be rolled along a track from its central station under the dome by the crank and gears at (25). 26—Conduit for electric wires from the instrument to the control desk. One lever engages with one movement the blades for all circuits. 27—Bolt to define the position of the instrument for use. Only when the instrument is in place for this bolt to be shot can the circuit contacts be made at (26). 28—Lamps which throw light upward for the general illumination of the chamber. They are shielded so that no light comes directly into the eyes of the audience. By rheostats these are dimmed or brightened for dusk or dawn, night or day.

PLATE IV



THE PLANETARIUM INSTRUMENT IN THE CHICAGO INSTALLATION.

instrument for it reproduces the intricate phenomena of the heavens. It shows the naked-eye stars, the Sun, Moon, and planets, all in their proper places for any instant of any year of any century for any terrestrial position. A high order of optical technique, mechanical skill, and astronomical knowledge are merged in its design. It may be best understood by aid of the accompanying diagram (Fig. 4).

At first sight it seems strange that the designer did not make the polar axis coincident with the long axis of the dumb-bell. This would have yielded some simplification in the representation of the stars, but the projectors for the Sun, Moon, and planets would then have had high inclinations to this axis and the driving of them would have entailed greater difficulties. Added difficulty would have been encountered in the representation of the precessional motion.

The stars, Milky Way, Sun, planets, and Moon, will be considered in this sequence. The starry heavens are produced by a mosaic of thirty-two separate fields. The plan for the partition of the sky for the individual star fields provided for the geometrical projection of the sky on the faces of a regular icosahedron whose twelve corners have been cut away to give a 32-sided solid with twenty regular hexagonal and twelve regular pentagonal faces. Each of these thirty-two faces then provides a picture which must be projected optically on the dome. At first, glass lantern slides were tried for the plates but later thin (0.0006 inch) cop-

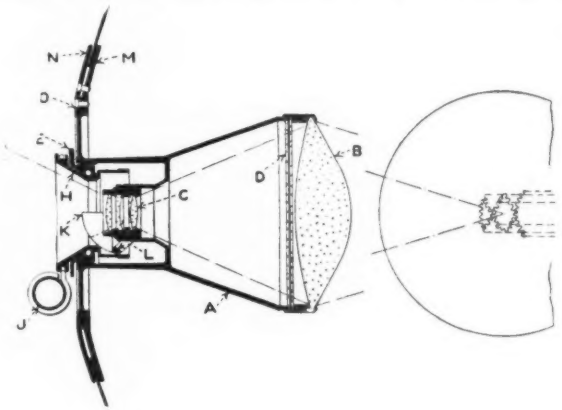


Fig. 5. Cross-section of Star Projector.

per plates perforated with holes of sixty-five different sizes to represent stars for the visual magnitudes 1 to 6.5 in steps of 0.1 magnitude were adopted. The difference of brightness for the various magnitudes is then accomplished by the different sizes of the star disks shown on the screen. The images of the fainter stars are scarcely one-eighth inch in diameter but the brightest stars are fully two inches and therefore

show decided disks. To the objectionable feature that the stars appear as disks instead of points and also to the distortion of constellations due to out-of-center viewpoint in a celestial sphere of restricted radius, the observer readily adapts himself. The unit star projectors are mounted individually and adjustably on the large spherical carriers. The carriers are twenty-nine inches in diameter of thin sheet brass (0.078 inch) and contain each, centrally placed, a 1000-watt lamp which furnishes the illumination for the star images.

Fig. 5 shows one of the star projectors in diagrammatic form and

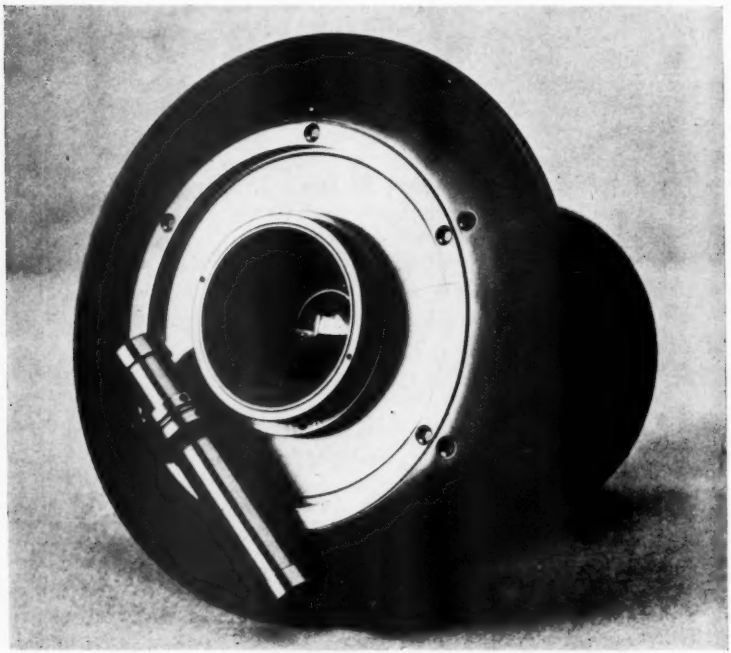


FIG. 6. ASSEMBLED STAR PROJECTOR SHOWING OCCULTING DEVICE.

Fig. 6 assembled. (A) is the container, (B) is the condenser, (D) the perforated plate, (C) the Zeiss Tessar projection lens, Aperture = 2.66 cm, F = 12 cm, (M) and (N) are the adjustment rings and (O) the clamp. Inasmuch as only that part of the sky above the horizon is to be shown, an occulting device is provided for each projector to shut off the light when the lens is pointed below the horizon. This is a spherical sector (K) which serves as a mechanical eyelid, not unlike the device used for dolls which open and close their eyes in appropriate posture. Its axis is mounted in the ring (H) which in turn has a ball-bearing mounting in the race (E). The axis is kept level by the weight (J), a

cylinder partially filled with mercury, which provides a delicate sense of level. Moreover, the edge of the shutter (K) is kept parallel to the horizon by the weight (L). The gradual covering of the objectives simulates well the atmospheric absorption near the horizon.

The individual fields, fitted together to give a complete and continuous picture of the sky, are adjusted with respect to each other by moving the projectors within the adjustment rings (M) and (N). This is done once for all when the instrument is erected in the dome. Temporary adjustment marks are provided for the purpose. This adjustment is a matter of great importance and considerable delicacy. No matter how accurately the individual star fields represent the stars within their areas, if they are not in accurate mutual adjustment there will be obvious distortions at the junctions. The position of each perforation in the star plates must be carefully calculated to allow for the distortion of geometrical projection, for optical distortion, and more critically still, for a parallactic displacement that enters because the spherical surfaces

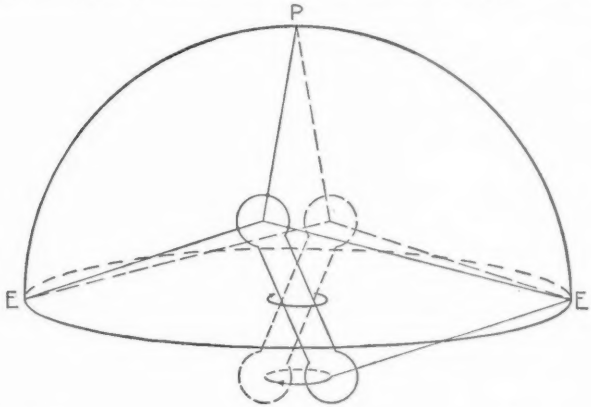


FIG. 7. DIAGRAM TO SHOW THE NEED FOR ALLOWANCE FOR PARALLACTIC DISPLACEMENT IN THE POSITIONS OF STARS ON THE PERFORATED PLATES.

of the carriers are not concentric with the dome and also because the axis of diurnal rotation does not pass through the centers of the globes. A star on the equator and one at the pole must be 90° apart on the hemispherical screen but it is readily seen from Fig. 7 that the perforations for them cannot be 90° apart. Neither can two perforations throwing star images to opposite points on the equator be 180° apart on the globes. When it is realized that 9000 stars are represented the amount of preliminary calculation can be appreciated.

On the spherical carriers are mounted also special projectors for the Magellanic Clouds, for Sirius, and on the Chicago instrument, projectors for three typical variable stars, Algol, Mira, and δ Cephei. A separate

projector for Sirius is provided that the great brightness might be attained by a brighter disk instead of one of excessive size. The lights for the variables are controlled at will by means of rheostats in the demonstrator's desk. Each of these special projectors has its own occulting device.

The spherical carriers bear also the cylindrical or drum projectors for the Milky Way. This feature of the sky is shown very realistically. A negative drawing of the Milky Way was prepared producing the different intensities by stippling with fine dots irregularly placed. This drawing was then photographed on a film. The film is wrapped within a double-walled cylindrical vessel in the center of which is the lamp. By half filling the narrow space between the walls of the vessel with mercury, the occulting of the part of the Milky Way below the horizon is neatly accomplished.

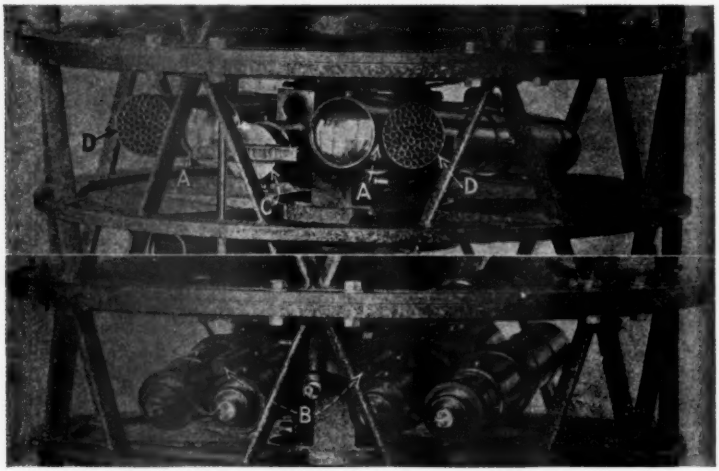


FIG. 8. FRONT AND BACK VIEWS OF THE SOLAR PROJECTOR.

It is not necessary to comment at length on the projectors for constellation names for they operate in the same manner as the star projectors even to the occulters. The names in general fall in vacant parts of the constellations. They may be turned on or off at will. That projector which covers the north pole of the ecliptic shows also the location of the poles of the planetary orbits and the circle described by the pole of rotation as a result of precession, dated to indicate the position of the pole in the different chiliads.

The images of the members of the solar system are thrown on the dome by individual projectors. These are located in the cage-like framework between the globes and the mid-section (Fig. 4). In all cases they are in pairs and of large aperture to minimize the effects of obstruc-

tion of the struts of the cages in which they are placed. Optically the planetary projectors are alike except that the images have distinguishing character. Mars is red, Jupiter has belts, Saturn has rings, Mercury and Venus are distinguishable by size. The Sun and Moon offer some optical differences.

The solar projector, of which front and back views are shown in Fig. 8, is complicated by serving a manifold function. With it is combined a

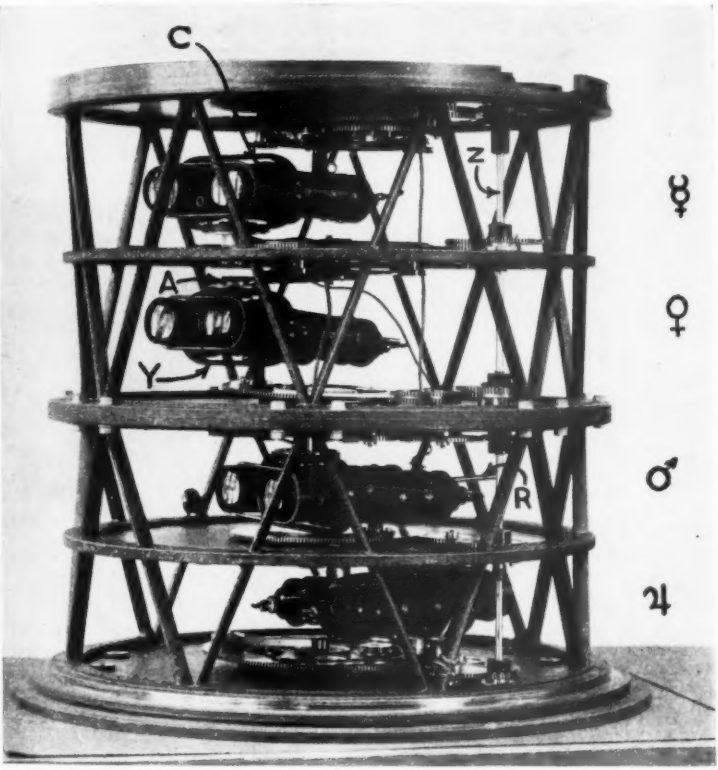


Fig. 9. Southern Section of the Planetary Cage.

device (D) for a halo of diffuse light centered on the Sun which by contrast blots out the fainter neighboring stars and which gives a glow at dawn forewarning of sunrise and at dusk above the hidden Sun. At (C) a series of prisms like steps of a stairway (see also Fig. 13) throws a faint glow along the ecliptic for the Zodiacal Light and at (B) are two small projectors to throw a faint patch of light to the opposition point for the Gegenschein.

Since the eccentricity of the Earth's orbit is slight, no account is taken of it in reproducing the Sun's apparent motion along the ecliptic. The solar projector is centered on the axis (2-2) of Fig. 4 and is driven uniformly by spur gears from the main annual driving shaft (Z) (Fig. 9). Inasmuch as the solar projectors are north of the plane of the ecliptic they are given a fixed inclination to bring the solar image upon that circle. The projectors for the Gegenschein are tilted similarly toward the opposition point. The brightness of the Sun may be varied by rheostat control but even at its maximum permits the view of the stars and accordingly the Sun's course among them.

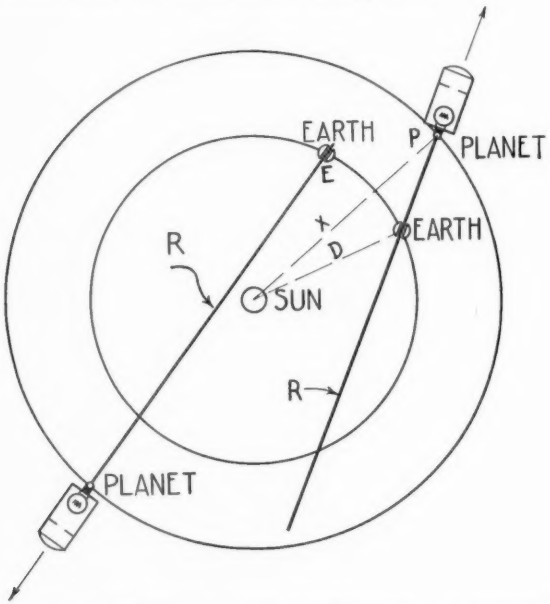


FIG. 10. TO SHOW THE PRINCIPLE OF THE ALIGNMENT OF A PLANETARY PROJECTOR.

Since in the sky we view the moving planets from a moving Earth their apparent motions are compounded of their own and the Earth's. In the planetarium the optical axes of the projectors in all cases and at all times must be directed along lines through the position of the planet and the Earth. All the vicissitudes that the different inclinations, non-commensurable periods, non-uniformity of speed introduce in the sky must be reproduced in the planetarium. Also, since none of these projectors can be in the plane of the ecliptic each must be given a tilt to bring the planet on the ecliptic when it should be at the nodes.

Each pair of projectors (Fig. 9) firmly bound together by a collar (C) is pivoted in the yoke (Y) free to rock about the long axis of the

collar. The yoke (Y) can be rotated about an axis (A). Figs. 10 and 11 show the principle by which the alignment of the projector is maintained in the case of an outer planet. The same principle holds for an inner planet Mercury or Venus with the roles (E) and (P) reversed.

Consider now just one planet. The aligning rod (R) passes through a sliding bearing carried on a universal joint at (E), the position of the Earth. The position of the planet (P) is on the axis (A) on the yoke mentioned above. As the positions of (E) and (P) change and their distance apart changes, the aligning rod (R) slips through the bearing at (E) which rotates and tilts, accommodating itself in all directions. At the same time the collar bearing the projectors tilts in the yoke which the while turns back and forth about the axis (A). In the planetarium the points (E) and (P) are carried on disks on opposite faces of the cage-chambers, one on the floor and the other on the ceiling. The terrestrial disk carrying the point (E) is centered on the axis (2-2) and is perpendicular to it. It is driven at uniform speed from the main planetary driving shaft (Z) by means of suitable reduction gears. A stud mounted on this disk carries the universal slide bearing (E) which may be raised or lowered to adjust the aligning rod (R) that it will

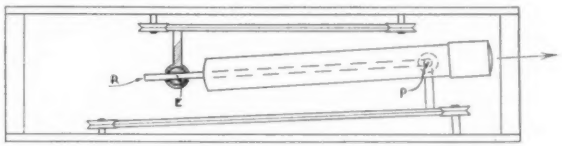


FIG. 11. SCHEMATIC VIEW OF A PLANETARY PROJECTOR.

point the projector to the ecliptic at the moments of nodal passages. Moreover, this stud is offset from the axis of the disk an amount (D) proportional to the Earth's distance from the Sun. The planetary disks for Venus, Jupiter, and Saturn, whose orbits have low eccentricities, are essentially like the terrestrial disk. Their centers are slightly offset from (2-2) to partially compensate for eccentricity, with the point (P) on the yoke-axis (A) at a distance (X) from the disk center in the proportion that D/X = ratio of the distances of the Earth and Planet from the Sun. The planetary disk is inclined to the terrestrial at an angle equal to the inclination of the orbit to the ecliptic. The terrestrial and planetary disks are not borne on central axes but are supported at the rims by three small sheaves. In general this device affords rigidity. It permits the use of fairly light disks without attendant tremors. It is of course apparent that any vibration of the axis of projection produces a greatly multiplied displacement on the dome, nearly a hundredfold.

For Mercury and Mars, where the orbital eccentricities are high (0.2056 and 0.0933) the angular velocity, which varies in the orbit inversely as the square of the radius vector, changes so considerably that it is not permissible to regard it as constant. A modification of the

simple planetary disk was adopted, whereby though still using a combination of crank motions with the initial disk driven at uniform speed, the point (P) moves in a circle and still changes its angular position in close agreement to true anomaly of the elliptic orbit. Three disks are employed. The upper, let us say, carries the axis (A) of the yoke, that is, the point (P). It is centered on the orbit's center, properly offset from (2-2), even as are the simpler planetary disks. The lower disk, which is the one driven from the main driving shaft (Z) is offset from (2-2) in the same direction but by twice the amount. The intermediate

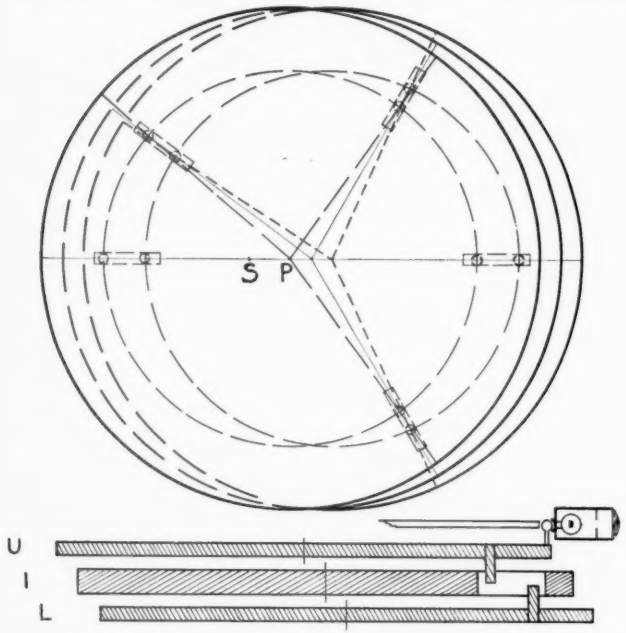


FIG. 12. SCHEMATIC REPRESENTATION IN PLAN AND ELEVATION OF PLANETARY DRIVING DISK FOR ORBIT OF HIGH ECCENTRICITY.

disk (I) is centered midway between. These three disks are (U), (I), and (L), in Fig. 12. A pin on the upper side of (L) engages in a slot in (I); also a pin from the lower side of (U) engages in this same slot. When (L) is driven uniformly, a point on the periphery of (U) describes an angular motion about (2-2) in close approximation to the variation of true anomaly. The greatest deviation from true position of Mercury, which is the most critical case, is less than one degree. This deviation is of course not cumulative. This triple planetary disk is tilted to provide for the inclination of the orbit as in the simpler cases.

In the southern cage an element of simplification and mechanical

economy is provided by having the terrestrial disks for Mercury and Venus back to back on opposite sides of the separating diaphragm between their chambers. The diaphragm is perforated and the disks are then one body with but one set of driving gears from the main shaft (Z). A similar economy is found for Mars and Jupiter. In the northern cage the annual drive of the Sun is carried similarly into the cage for Saturn and also into the lunar cage where it is applied to the gear train of the lunar phase meniscus to be described later.

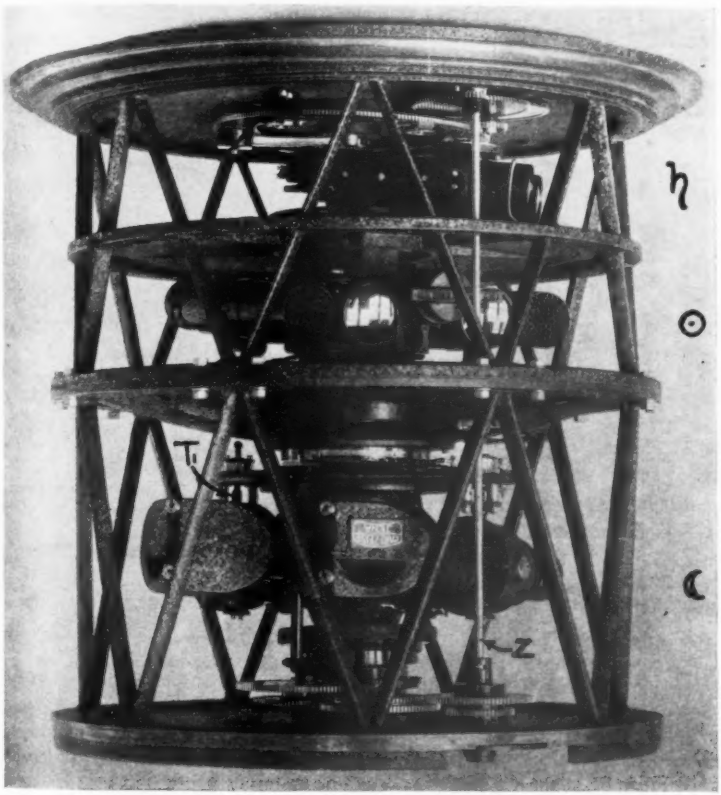


FIG. 13. NORTHERN CAGE CONTAINING THE PROJECTORS FOR THE MOON, THE SUN, AND SATURN.

As stated in an early paragraph, Huygens discovered the principle of continued fractions in designing his mechanical planetarium in 1682. Since that time this principle has been employed in all similar gear problems where it is desired to approximate the ratio of incommensurable periods. Application of the principle to Mercury yields, after some

adjustment, for the number of teeth of the gears

$$(45 \times 66 \times 86)/(65 \times 91 \times 104) = 0.41520905$$

This figure when divided by 1/10, the ratio of speed of the terrestrial disk to the main planetary shaft (Z), gives 4.1520905 which is a close approximation to the true ratio of the Earth's and Mercury's sidereal periods, 4.15209106 : 1. The teeth numbers are large enough to give smooth motion and yet not so large as to require large gears or, to avoid that, small teeth. The error in the ratio is so small that the accumulated residual will amount to one degree only after five thousand planetarium years. For the other planets an accuracy of the same order is attained.

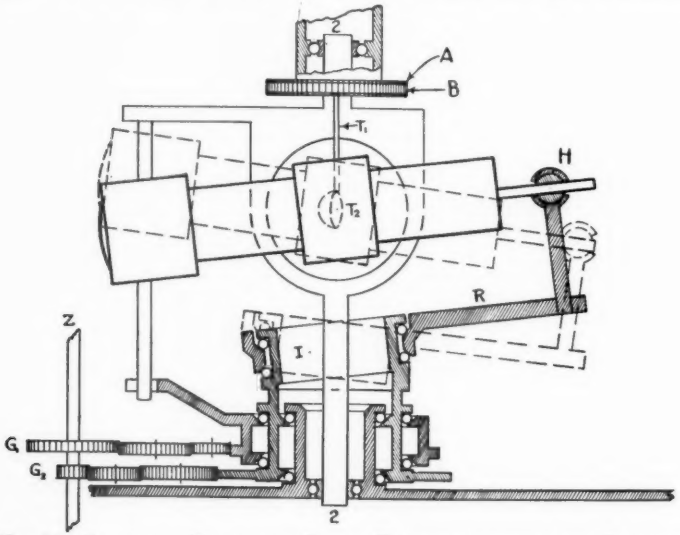


FIG. 14. SCHEMATIC DRAWING OF LUNAR PROJECTOR SHOWING THE LOCATION OF THE PHASE MENISCUS AND THE DEVICE FOR ACCOMPLISHING THE REGRESSION OF THE NODES.

The projector for the Moon (Fig. 13) provides the only perturbation that is represented, the 18.5995-year period of regression of the nodes. The lunar projector carriage is centered on the axis (2-2) and is driven about this axis in a period of one sidereal month. Under the projector and centered also on (2-2) is an inclined plane member (I) (Fig. 14) which controls the inclination, 5° 9′. If for a moment we neglect the regression of the nodes the lunar projector would rotate about (2-2) changing its tilt by rocking in the bearing perpendicular to (2-2) and to the line of projection, being constrained so to do because the guide rod (R) is attached to a plane rolling on ball bearings on the inclined plane (I). In one rotation the Moon would make its migration above and below the ecliptic and would always reach its nodes at the same

longitudes and come to the points of maximum latitude among the same stars. If now the gears which make the monthly revolution are disengaged and the inclined plane member is set to rotating in its equivalent period of 18.5995 years, the inclination of the lunar projector would slowly change until in the half-period the projector would be pointing as far above the ecliptic as nine years earlier it had pointed below. The bearing on the guide rod (H) must be a universal slide bearing. Both the lunar projector and the inclined block are driven from the main planetary shaft (Z) through independent gear trains (G_1) and (G_2). With the monthly and nodal regression motions both in operation, the Moon will go through its configurations and stations with the nodal points slowly moving westward along the ecliptic. This is a very necessary feature of the instrument for without it the planetarium would be wholly useless for reproduction of eclipse configurations.

Another interesting mechanical and optical device provides that the Moon appear in phase appropriate to its configuration. In Fig. 15 the

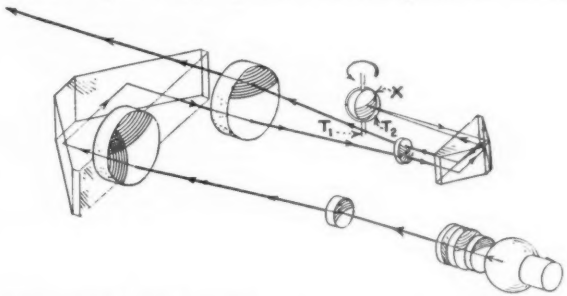


FIG. 15. PATH OF THE BEAM THROUGH THE LUNAR PROJECTOR.

path of the beam from the lamp may be easily followed through lenses and totally reflecting prisms until it strikes a small metallic concave mirror (X). Projection of the image of this mirror when fully illuminated gives full moon; fractional illumination yields the lesser phases. Pivoted on an axis (T_1) aligned with the reflecting face of the mirror and perpendicular to the ecliptic is a closely fitting hemispherical meniscus or cup (T_2) which rotates on its axis in a period of one synodic month. Since the edge of this hemispherical shell will project always as an ellipse, it will properly represent the terminator.

As noted previously the annual motion of the Sun is transmitted directly into the lunar cage. The central axis carrying the solar projector and aligned on (2-2) protrudes into the lunar chamber and there carries a spur gear (A) (Figs. 14 and 16). Meshed with this gear through idlers (B, B), mounted on the lunar projector carrier are others (C, C) having the same number of teeth as (A), their axes carrying in prolongation the axes of the occulting cups which, as noted above, are therefore perpendicular to the ecliptic. The design has placed the cups

in prolongation of the axes about which the lunar projectors oscillate perpendicularly to the ecliptic so that they stand always at a fixed distance from the top of the cage. If the gear (A) (Figs. 14 and 16) from the solar projector were fixed instead of in motion the lunar drive carrying the projectors through an angle 1/M would rotate the cups a like amount and in one rotation, that is, in a sidereal month, would rotate the cups through 360°. But, because (A) is rotating with a period of one year it automatically and with the utmost simplicity lengthens the period to one synodic month, for in one day it would turn through an angle 1/E thereby retarding (C) by a like amount. The relation $1/M - 1/E = 1/S$, where E is the year, M the sidereal month, and S the synodic period, is maintained. The horns of the crescent Moon point along the ecliptic and not exactly away from the Sun but the error is not perceptible except when the Moon is very near the Sun and only then when near its greatest celestial latitude. But since the Moon is scarcely to be seen within one day of conjunction the malposition of the terminator will in general escape notice.

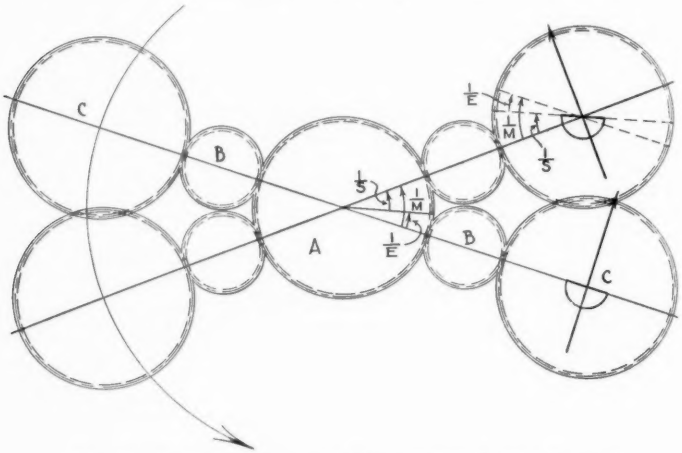


Fig. 16. Device to Drive the Meniscus for Lunar Phases with the Synodic Period.

The main planetary driving shaft (Z) in its two sections provides that the solar, lunar, and planetary motions take place in perfect synchronization for the gears are all interlocked. The terrestrial disks all rotate with one-tenth the speed of the shaft (Z), the planetary disks in strict proportion.

The locations of the sets of projectors which throw the principal astronomical reference circles on the dome are indicated on the diagram of the instrument (Fig. 4). The projectors for the equator and ecliptic (13, 14) must of course move with the instrument and the circles which

they project travel with the stars, being displaced only by precessional motion. By a series of lenses full circles are projected on the sky, the ecliptic graduated in daily dated stations of the Sun, the equator graduated to indicate right ascension. The projectors for the meridian (15, 16), on the contrary, are fixed on the standard. As our horizon is always with us, fixed in the chamber, so are the zenith and meridian. Illuminated letters, N, E, S, W, faint of course so as not to be obtrusive, stand along the horizon at the cardinal points. At each point is also the letter of the opposite point for as one travels on a meridian over the pole all directions reverse. These graduated reference circles are useful for instruction in the coördinate systems and their interrelation, and even for the solution of simple problems in practical astronomy and navigation.

The over-all length of the great dumbbell is twelve feet. The center of motion which is in the plane of the horizon is 9.81 feet above the floor. The weight of the movable parts approaches a ton. The support for it is built of steel in lattice-work fashion of the thinnest allowable members consistent with the demand for freedom from vibration or oscillation, just as in the planetary cages the struts are thin and placed edge-on to the line of projection that the obstruction shall be as slight as possible.

There are four distinct types of motion: that for change of latitude; the diurnal motion; the interlocked motions of the Sun, Moon, and planets; and the precessional motion.

The first of these is wholly independent of the others. The motor drives the whole movable part of the instrument about the axis (3-3) (Fig. 4) perpendicular to the meridian, thereby changing the inclination of the polar axis (1-1) and producing a change in the aspect of the sky like that resulting from change of latitude. The arrow-head markers for the poles move along the graduated meridian and permit the latitude to be read directly by the polar altitude. The alternative method of reading the zenith distance of the intersection of meridian and equator is also available. The period for the 360° circuit is $5^m\,8^s$.

There are two motors for the diurnal motion which rotate the instrument about the axis (1-1) (Fig. 4) in periods for the sidereal day of $3^m\,12^s$ or $1^m\,4^s$. These motors can be operated together or opposed, yielding periods of 48^s or $1^m\,36^s$.

The synchronized solar, lunar, and planetary motions, commonly referred to as the annual motions, take place within the body of the instrument. There are three motors which in the Chicago instrument used singly operate at the rates of a year in $3^m\,3^s$, 61^s, and $5^s.8$. They may be run in any combination forward or backward. The shortest possible year with all in either forward or backward motion is $5^s.1$.

The remaining motion is that about the axis (2-2). This reproduces the precession of the equinoxes, for it changes the direction in which the ecliptic faces with respect to the equator and sends their points of inter-

section, the equinoxes, in westward motion. The stars move parallel to the ecliptic changing right ascension, declination, and celestial longitude, but with celestial latitude unchanging. In nature the precessional cycle requires 25,800 years; in the planetarium $1^m\,16^s$. As the equinoxes move, the pointer at the equatorial pole moves about the pole of the ecliptic in a circle of radius equal to the obliquity of the ecliptic. As noted earlier this circle graduated in chiliads is thrown on the dome by a projector in (7) (Fig. 4).

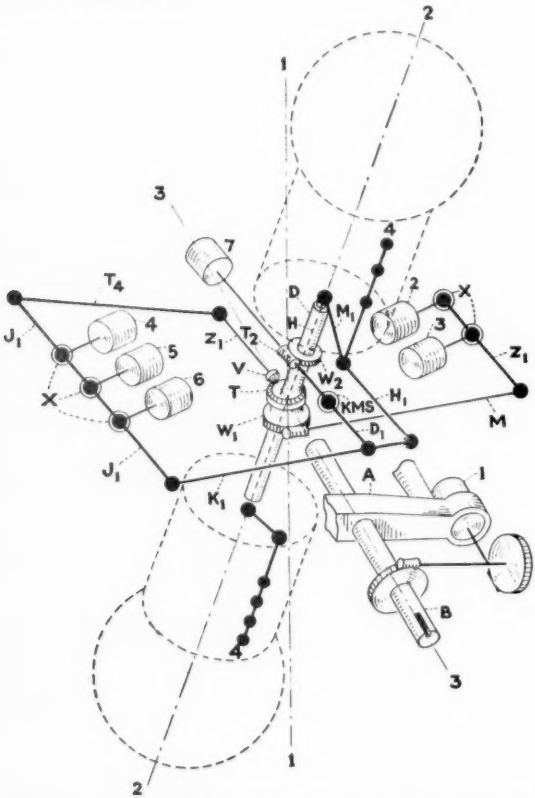


FIG. 17. COMPLETE DESIGN OF MOTOR DRIVE IN SCHEMATIC FORM.

The diurnal, annual, and precessional motions are not wholly independent but are interconnected in some operations mandatorily but not necessarily reciprocally. Thus the operation of the diurnal motion carries with it the commensurate annual and precessional motions, but neither the annual nor precessional carries the corresponding diurnal. The operation of the annual motion requires the proportional precession-

al change but the reverse is not true. So in general, the motions which in nature are of short period carry with them in the planetarium operation those of longer period and this of course either backward or forward in time but the reciprocal action does not hold. This does not imply that the daily motion may not be operated when the annual is on, or when the precessional is on, nor that the annual may not be used when the precession is in operation, nor that the independent precessional or annual motions may not be superposed on the proportional automatic ones. Various combinations are possible but the automatic connections are as stated. Some combinations give very curious results.

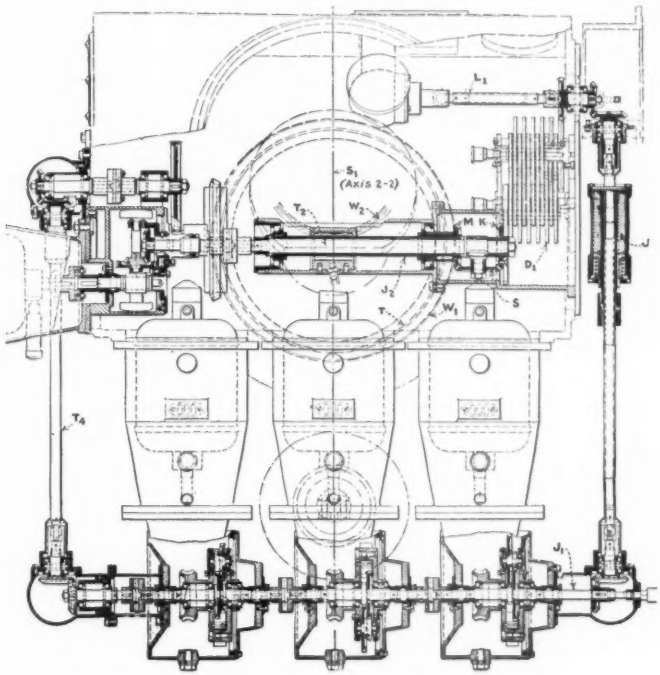


FIG. 18. DETAIL OF THE ANNUAL AND PRECESSIONAL DRIVES.

Since diurnal and annual speeds of nearly equal periods are provided it is possible by using the two together to have perpetual noonday. Also, with a backward precessional motion and a forward annual motion one may have perpetual spring. Fig. 17 shows the general course of transmission of the motions and Fig. 18 some interesting details of the transmission.

It is not necessary to elaborate on the change of latitude drive. As noted before, this motion is entirely independent. Its method of applica-

tion from the motor (1) through two worm gears is apparent in Fig. 17.

The three annual motion motors (4, 5, 6) (Fig. 17) transmit by (J_1 K_1 H_1) to the planetary shaft in the north cage and by (M_1) and a shaft through the perforated precessional axis (2-2) to the planetary shaft in the south cage. The planetary shaft is here number (4, 4). Heretofore it has been designated (Z).

At (D_1) a shaft is taken from (K_1) to transfer the annual motion to the precessional axis for proportional motion. A multiple reduction involving a 3000-fold step-down is shown in Fig. 18 at (D_1). Thirteen gears are involved between (K_1) and the bevel gear (K). The bevel gear (M) is mounted on the head of the precessional driving worm shaft which turns the worm wheel (W_2) and thereby rotates the instrument about the axis (2-2). The worm shaft is perforated and the shaft (T_2) from the precession motor (7) passes through it (Fig. 19). The motion

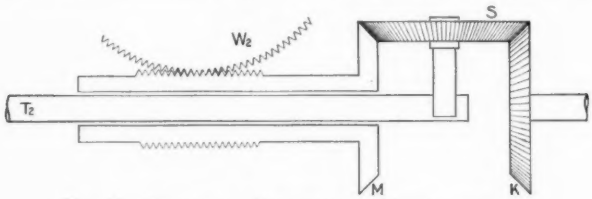


Fig. 19. Detail for Precessional Motion and the Annual Increment Thereof.

from the annual train and from the precession motor (7) are both applied to the gear (M) through the intermediate bevel gear (S), the axis of which is a pin through the shaft (T_2). If the annual motion is running, the gear (K) will drive (S) and thereby (M) and the worm (W_2) in the proper ratio to the year. The axis of (S) will remain fixed in direction. If, however, the precessional motor (7) is running, the shaft (T_2) will turn and with it of course the axis of the gear (S), entailing motion of (K) or (M) or both. But since (K) is practically locked by the manifold gear reduction it stands fast and (M) is driven. The annual motors then deliver automatically the attendant precession but the reverse does not apply.

The diurnal motors (2) and (3) (or 18 in Fig. 4) transmit their motions through the shafts (Z_1) and (M) to a worm (W_1) mounted as an integral part of the cradle which carries the whole instrument in its bearing on the axis (3-3). With either or both of these motors in operation the instrument is driven about the polar axis (1-1). The bevel gear (T) turns with (W_1) and through the pinion (V) and shafts (Z_1, T_4) drives the main annual motion shaft (J_1) and so through the whole train for the proportional increment of annual motion and even the precessional motion.

From the rapidly turning annual motion motor to the creeping precession requires extraordinary gear reduction. There are 25,800 years

in the precessional cycle. If the motor makes 1600 RPM and if the year required exactly one minute, the reduction would be 41,280,000 to 1. For the $5^{s}.8$ annual motion this would be 3,990,400 to 1. The greatest reduction is from the slowest diurnal motion by the circuitous route through the annual motion to precession, where the reduction, providing the motors run at 1600 RPM, would be 48,248,064,000 to 1.

The wiring for the electric circuits is another interesting feature of the instrument. The lamps in the great globes for the star projectors are 110 volts, 1000 watts. For the other multiple projectors for constellation names, circles, etc., they are 30 volts, 100 watts; and for Sun, Moon, planets, Sirius, variable stars, etc., they are 6 volts, 10 watts. The commutators on axis (3-3) may be seen in Fig. 4 at (22). There are thirty rings for the distribution from the pedestal to the movable parts of the instrument at this stage. There are other distribution rings on the great plate in the equatorial plane and also on either side of this in the plane of the ecliptic. They provide unbroken circuits with entire freedom of motion about the axes (1-1), (2-2), and (3-3). For the planets there are individual rings with sliding spring contacts. The electric circuits are led down the frame in small tubes and make contacts with the cable leading to the control board by a many bladed knife switch under the standard at (26) (Fig. 4).

The control board (Fig. 20) at first glance seems fairly complex but it is logically arranged and sufficient mastery to enable the demonstrator to operate it in the dark or with dim light is soon acquired. Considerable experience and practice are needed, however, before the demonstrator can without hesitation make the correct contacts. If from inexperience he must divert attention from the thought of his lecture to consider the operation of the switch-board, his discourse is interrupted or perhaps incoherent. A novice should not drive an automobile in city traffic. Fortunately in the planetarium no damage can result from turning the wrong switch except that to the speaker's complacency. It is a matter of chagrin to prepare an audience for the approaching trip to the pole and find instead the equinox moving among the stars with swiftly rolling centuries. An obvious solution is to have a trained operator and free the lecturer from the responsibility. But more freedom, more elasticity, more spontaneity are available if the demonstrator manipulates the controls.

A considerable number of astronomers have presided at the control board of the Adler Planetarium in public demonstration. The Director has given 554 lectures, the Assistant Director Miss Maude Bennot 420, Demonstrator F. W. Schlesinger 151. Besides these regular members of the staff, the following have participated as guest lecturers: Walter J. Bartky 171, Dinsmore Alter 122, W. D. MacMillan 63, C. H. Gingrich 34, R. H. Baker 33, D. W. Morehouse 26, Elliott Smith 18, E. A. Fath 10, W. H. Garrett 9, James Stokley 7, Joel Stebbins 6, Ralph C. Huffer 5, H. T. Stetson 3, E. J. Moulton 3, Giorgio Abetti 1, Clyde Fisher 1.

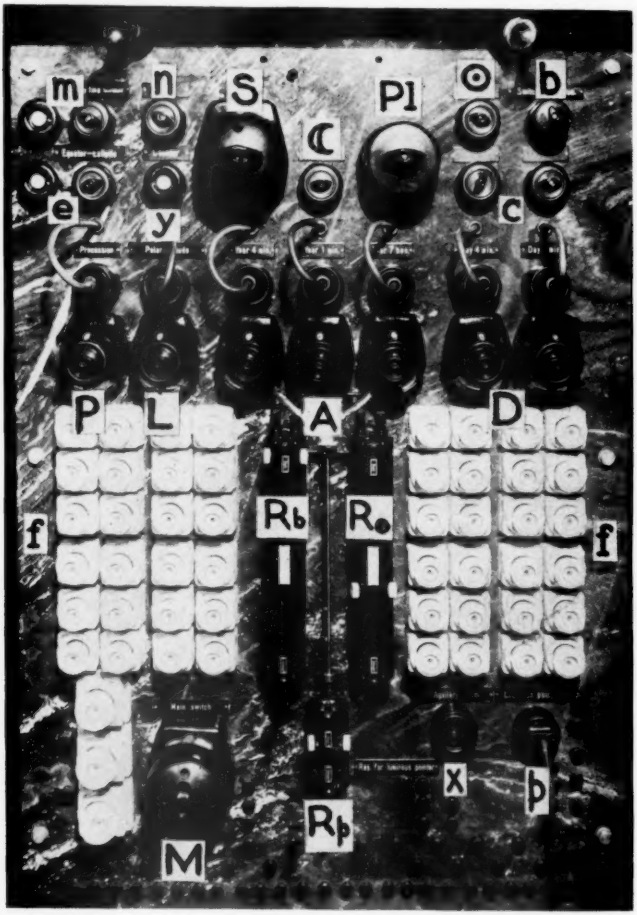


FIG. 20. CONTROL BOARD AT THE DEMONSTRATOR'S DESK, WHICH IS ENCLOSED TO CONFINE ITS FAINT ILLUMINATION.

m—Meridian. A push button for momentary presentation (extinguishes on release) and switch for longer showing. e—Equator, ecliptic, and sections of hour circles. Button and switch. y—A button for the year counter. n—Constellation names. S—The stars. ☾—Moon. Pl—Planets. ⊙—Sun. c—Cardinal points. b—Switch for control-board lights. The lamps are seen at the top of the board. Ordinarily these are hooded. P—Precessional motion. L—Change of latitude. A—Annual motion, slow at the left, intermediate in the center, and fast at the right. D—Diurnal motions, slow at the left and fast at the right. Rb—Rheostat for adjustment of control-board illumination, the lights (b). R⊙—Rheostat to control the brightness of the Sun. Rp—Rheostat to control the brightness of the optical pointer. p—Plug for optical pointer. x—Extra line. f—Fuse plugs. M—Master switch.

The master switch for connecting all circuits is at the bottom of the board (M) (Fig. 20). All switches for projectors are in the top section of the board; all for motions are in the row (P, L, A, D) across the upper center of the board.

By reversing the plugs above the seven switches (P, L, A, D), the directions of motion are reversed. The seven motors under instant control by the several switches may be operated in as many different ways as there are possible combinations, having in mind that any or all of them may be arrested or reversed. Mathematically there are 2187 possible combinations, including the one when all circuits are dead. The vast majority of combinations serve no logical or illustrative purpose. For example the use of all seven in any possible combination of direct or reverse would produce an almost meaningless phantasmagoria. The

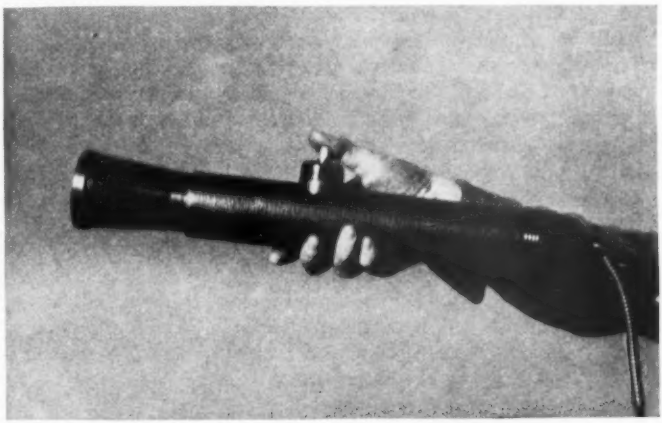


Fig. 21. The Optical Pointer.

combinations actually used are comparatively few, less than two score. Certain interesting combinations to give perpetual noonday or eternal spring have been previously cited. Just as certain combinations are of interest so also certain sequences of motion are of value; for example, the change of latitude to bring the pole to the zenith to be followed by diurnal motion to show the movement of the stars on the "parallel sphere."

Ready to the hand of the demonstrator is an optical pointer (Fig. 21). It is plugged into the switchboard at (p). Its brightness may be controlled by (Rp). It is a focusing lamp which throws an image of an arrow on the dome. As it is held in the hand any point of interest can be indicated. Care must be exercised to use it sparingly, to move it slowly, to hold it steadily on the object, to extinguish it when it has served its purpose. Rapid motion of this arrow or unsteady holding

or excessive brightness is annoying.

The remaining features of the control station are the switches and rheostats for the lights (28) (Fig. 4) which furnish the general illumination of the chamber, and the rheostats to produce the change of brilliancy of typical variable stars. This feature of variable stars is new with the Chicago instrument.

Near the demonstrator's desk there is an auxiliary projector for showing lantern slides. These may be flashed on the dome as in any ordinary illustrated lecture. In pointing out the Great Cluster in Hercules, for example, a picture of it might be projected on the dome to show its appearance in a great telescope. For such purpose the lantern is of great value.

In the Adler Planetarium certain accessory apparatus has been developed for use with the stereopticon to reproduce the phenomena of eclipses, meteoric showers, aurora, etc.

The planetarium affords means for illustration of a great variety of astronomical phenomena, too many to present in a single lecture. At the Adler Planetarium twelve topics have been selected which serve fairly well as vehicles to show the various possibilities of the instrument. The topics rotate, each one serving for a month.

January—Winter Constellations of the Home Sky.
February—Time and Place.
March—The Calendar.
April—The Moon and Its Motions.
May—The Way of the Planets.
June—The Midnight Sun; the Heavens at the North Pole.
July—Summer Constellations of the Home Sky.
August—The Southern Sky; the Southern Cross.
September—The Seasons; the Annual Journey of the Sun.
October—The Great Precessional Cycle.
November—Objects of Special Interest in the Sky.
December—Architecture of the Heavens.

In devising a program it is obvious that the method of presentation must differ in several respects from that of the university class room. For the audience there are no intellectual prerequisites; there is mixture of age and interest through wide range; there are some making their initial visits, others who have been frequently in attendance. There can be, therefore, no strictly formulated progression. Each lecture must be measurably self-contained. Some features are common to all demonstrations for each includes a brief description of the instrument and exhibits the phenomena of diurnal and annual motions. Beyond this, emphasis is placed on items particularly associated with the topic for the month. What these must be is obvious in most cases but even so, careful consideration is necessary if repetition is to be avoided and discourse and sequence of events are to fit in orderly and natural fashion.

January and July are devoted to constellation study. Methods and history of nomenclature are discussed. The ancient star groups and the principal stars are pointed out; where they may be seen at different hours at different seasons. The lantern lends its aid with slides of the constellation figures, slides of paintings or sculptures portraying the old stories of mythology and of temples oriented to certain stars, and slides of interesting astronomical objects in the constellations. No Chicago youth can in later years cry out with Carlyle: "Why did not someone teach me the constellations and make me at home in the starry heavens?"

Time and Place brings emphasis to the systems of reference circles and coördinates. The circles are projected on the dome. Solar time, sidereal time and their relation; the inequality of apparent solar days; the equation of time and need of mean time can be exhibited very simply. The change in aspect of the sky with change of latitude may be seen; the altitude of the pole or meridian zenith distance of the equator can be read directly.

The Calendar continues the previous topic with the consideration of the adjustment of the incommensurable units of day and year. An interesting feature in this lecture is the demonstration of the Metonic Cycle, the equality of 235 months to nineteen years.

The Moon and Its Motions includes an explanation of the phases, the reason for great meridian altitude of the full Moon of winter and *vice versa*, the orbital inclination, the Harvest Moon, the regression of the nodes, eclipse of the Sun and Moon. For the exhibition of eclipses special apparatus has been devised and constructed.

In *The Way of the Planets* the phenomena of planetary motions are considered more thoroughly. The rapid annual motions are here of greatest value. The looping of the apparent paths in the sky, the retrograde motions, critical or multiple conjunctions are exhibited very vividly. It is beautiful to see the planets describing their rhythmic arabesques among the stars. The triple conjunction of Jupiter and Saturn in 1940-41 is nicely shown. The agreement of the dates with those yielded by calculation demonstrates the usefulness of the instrument for approximate computation.

The Midnight Sun of course requires that the Sun be at the summer solstice and that the observer be on the arctic circle or still farther north if the solar declination is less. The place and time for the Sun's setting are observed, first in the latitude of Chicago, then farther north until the phenomenon of the Midnight Sun is revealed. The hour of sunset can be read by the projected coördinates, its place can be noted by the buildings of the Chicago skyline cut in silhouette along the horizon. At the pole the circling of the Sun, planets, and stars along almucantars, with the pole star near the zenith, shows the parallel sphere. The Sun sets at the autumnal equinox and in the arctic night the aurora borealis appears. For this a simple piece of apparatus (also designed here) serves admirably.

The Southern Sky: the Southern Cross is treated in much the same manner as the lectures on constellation study. On the way south a pause is made at the equator to show the right sphere.

The Seasons: the Annual Journey of the Sun is one of the most effective lectures. The course of the Sun along the ecliptic, the low short arc of the Sun in the winter day (counting the hours), the long night, and reciprocal conditions in summer, give convincing explanation of summer's heat and winter's cold. The changing meridian altitude of the Sun through the year is neatly shown by running the diurnal and annual motions together, using the nearly equal periods, so adjusted as to give perpetual noonday, itself an interesting phenomenon.

The Great Precessional Cycle is the topic perhaps of greatest interest to astronomers because the change of the sky from precession in a human lifetime is so slight that acquaintance with it, while of great interest, is generally encountered as an annoying consideration in dealing with star positions. It is very strange to see the swift motion of the stars in circles parallel to the ecliptic, to see the equinox moving among them and the pole reeling about the pole of the ecliptic. It is curious to see the sky of 3000 B.C. with Thuban (Alpha Draconis) as the pole star, with the Vernal Equinox in Taurus, the Southern Cross appearing above the Chicago horizon; or leaping far into the future, 14000 A.D., to see Vega as the pole star, the Vernal Equinox in Virgo, Sagittarius high in the sky and holding the summer solstitial point, Alpha Ursae Minoris setting, the Southern Cross again appearing, and Orion far from the Equator, at upper culmination only half above the horizon. An interesting variation can be accomplished by running the precession against the synchronized annual motion and thereby attaining perpetual spring or eternal summer. The lecturer with simple apparatus shows the relationship of astronomical precession to the familiar gyroscopic motion of spinning objects here on Earth.

Objects of Special Interest in the Sky takes up in sequence the different kinds of objects: proper motion stars, double stars, giant and dwarf stars, variables, multiple stars, clusters, nebulae, pointing them out, showing slides of them and about them. The rheostat control of the variables is used very effectively here. In this lecture (partly because it is given in November) a meteoric shower is projected realistically on the screen with the radiant in Leo. This is produced by a device which has been made in the instrument shop of this institution.

The *Architecture of the Heavens* may serve either as an introduction to the series or a summary of the whole. The method of star counts to demonstrate galactic concentration is illustrated. The Milky Way, so beautifully portrayed, takes on its true significance. By putting the nodes of the galactic plane at the east and west points and then changing latitude, it is possible to bring first one pole of the galaxy then the other to the zenith. When this is done our solar system is shown to be well to the north of the median plane.

It is possible to vary these lectures for any purpose at will. For example, on two different occasions Officers of the U. S. Navy stationed in the vicinity of Chicago, Naval Reserve Officers, the Naval R.O.T.C. Unit of Northwestern University, and Army Officers of the Air Service, have attended special demonstrations for instruction in the astronomical phases of navigation, or perhaps it were better to say, demonstrations to illustrate the applicability of the planetarium for such instruction. While the contents of the lectures may be varied *ad libitum* the twelve topics outlined above have been adopted for the scheduled demonstrations.

The minimum schedule of demonstrations of the Planetarium, operative in winter, offers lectures each week-day at eleven o'clock in the morning and at three in the afternoon. In addition there are lectures at eight in the evening on Tuesdays and Fridays; on Sunday afternoons lectures are given at three and four. In summer this program is expanded by additional lectures in the afternoons and evenings.

The response of the public has been very gratifying. The attendance during the first year was 731,108. The million mark was passed on the twenty-first day of the sixteenth month. The average daily attendance for the first nineteen months was 1,951. No record is available to show how many of the total have made more than a single visit. Certain it is that there are many who attend frequently and many who announce that they are attending each month to hear the complete cycle of lectures, some oftener than once a month. The large attendance is the more gratifying when it is realized that the building is more than a mile from street car or elevated transportation: only busses and taxis are available for public conveyance. Moreover, the approach to the building is as yet none too inviting. The way to the island leads across the lagoon by a temporary wooden bridge, which in rough weather may be swept by waves, and then a bleak third of a mile on a dirt and cinder road or path. The installation of the great bridge and the completion of the landscaping will totally change this aspect.

The visitors come to see a stirring spectacle, the heavens brought within the confines of museum walls. Not a trivial plaything, a mimic aping firmament, but the heavens portrayed in great dignity and splendor, dynamic, inspiring, in a way that dispels the mystery but retains the majesty, a revelation of the sky so beautiful that with Milton one may say

> ". . . . fragrant the fertile Earth
> After soft showers, and sweet the coming on
> Of grateful evening mild; then silent night
> With this her solemn bird and this fair Moon
> And then the gems of heaven, her starry train."

(A second paper, pertaining specifically to the Astronomical Museum, will follow in an early issue of this magazine.)

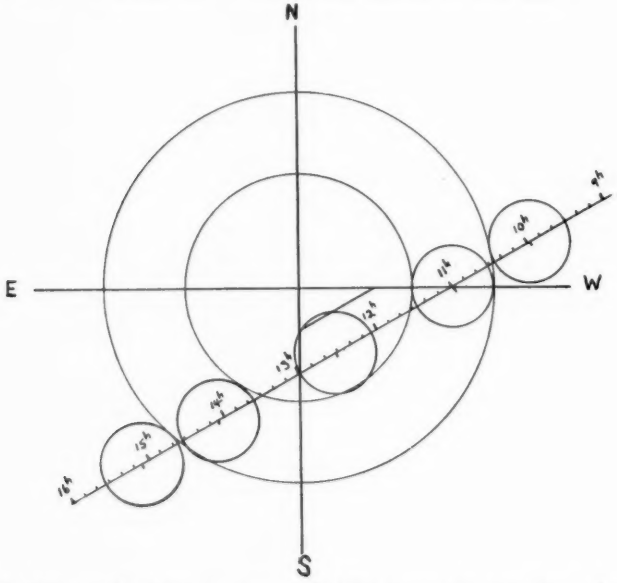
Adler Planetarium and Astronomical Museum,
Chicago, Illinois, 1 January 1932.

Lunar Eclipse of March 22, 1932

By RALPH C. LOWE

The accompanying diagram is a graphic representation of the lunar eclipse which occurs March 22, lasting from about 10 hours to 15 hours, G.C.T.

This eclipse is not visible in the vicinity of Philadelphia, the moon setting just about the time the moon enters the umbra; however, on the West Coast the whole of the total phase should be well seen.



The data for the diagram were obtained from the *American Ephemeris*, Professor Rigge's method being used.

The two circles represent the umbra and penumbra of the earth, with N S E W axes, and the graduated line is the moon's path expressed in G.C.T., having the moon's disc struck at the proper points of contact. The short line parallel to, and just above the moon's path, is the graphic expression of the moon's orbital hourly motion, and is used in calibrating the moon's path.

The hours of the phases are:

	h	m	
Moon enters penumbra	9	58	G.C.T.
Moon enters umbra	10	59	
Middle of eclipse	12	32	
Moon leaves umbra	14	05	
Moon leaves penumbra	15	06	

The above items check within one minute of the numerically computed values in the *Ephemeris.*

The position angles of contact measured at the center of the moon's disc are

First contact 90° E. Last contact 32° W.

The moon will be in Longitude 173 East and in Latitude 1 South at the time of mid-eclipse.

The Diurnal Path of a Shadow

By C. C. WYLIE

To obtain a simple solution of this problem, we will omit refraction, parallax, semi-diameter, and daily motion of the sun. We will also assume that the shadow is falling on a horizontal plane. A simple illustration would be the shadow of a ball on the top of a flagpole, the flagpole being placed in a large level court.

With these assumptions, a line from the ball to the sun will in the course of twenty-four hours sweep out a cone. This will be easily understood by imagining an equatorially mounted telescope substituted for the ball. Those who have used telescopes are all familiar with the fact that if a telescope is kept pointed at the sun throughout the day it, in general, sweeps out a cone. The axis of the cone is the polar axis of the telescope, which is parallel to the axis of the earth. As the shadow of the ball at any particular instant is on the line from the ball to the sun, extended in the opposite direction, it is obvious that the curve described on any particular day will be the intersection of a horizontal plane with the cone swept out on that day by the line joining the sun and the ball produced.

From considerations given in the early chapters of standard texts on descriptive astronomy, we know that the elements of this cone make with the axis the angle $90° - D$, where D is the declination of the sun. We have said that the axis of the cone is parallel to the axis of the earth. Hence, it makes with the horizontal plane an angle equal to the latitude.

From these facts and elementary geometry it follows that for latitudes less than $90° - D$, the intersection of the cone with the horizontal plane is a hyperbola. For the latitude $90° - D$, the intersection is a parabola, and for greater latitudes it is an ellipse. The physical significance of this mathematical result is that, if the sun goes below the horizon for part of the twenty-four hours, the path of the shadow of the ball is a hyperbola; if the midnight sun is just on the horizon, the path is a parabola; while if the midnight sun is above the horizon, the path is an ellipse.

In the torrid and temperate zones, the paths during the northern

spring and summer are hyperbolas concave to the north. At either equinox the path is a straight line. Throughout the northern autumn and winter the hyperbolas are concave to the south. The fact that the path of the shadow is a straight line at either equinox will be obvious if one thinks of an equatorial telescope pointed toward the sun at that time. The telescope will then be at right angles to the axis of rotation and will obviously sweep out a plane as it turns. The intersection of this plane with the horizontal plane would be a straight line. In the frigid zones, there are some days when the sun does not show at all, and hence there would be no shadows. When it shows part of the day the path of a shadow is a hyperbola. The path is a parabola when the midnight sun is seen on the horizon; and with the sun above the horizon throughout the twenty-four hours, the path is an ellipse.

The shadow at the pole is a special case of the elliptical path. When the sun is above the horizon, the path on any particular day is a circle. The radius is infinite at the spring equinox when the sun is on the horizon; and the circles decrease until the summer solstice when the sun is 23½° above the horizon. The circles then increase until the autumn equinox, when the radius is again infinite. The circular path of the shadow simplifies the approximate method of locating the pole. A stick, or spear, could be driven into the snow and the surrounding area leveled off. If throughout the next twelve hours the shadow of this stick is practically the same length, it is obvious that the stick must be set up very nearly over the pole of the earth. Practically, the drifting of the floating ice would make this method uncertain at the north pole, but on the south polar continent it could be used if a sextant were not available. This is equivalent to observing the altitude of the sun with a sextant and repeating the observations from time to time to see whether or not there is a change in the observed altitude of the sun. If, after twelve or more hours, there is no change, excepting that due to the change in the sun's declination, the pole has been located. If there is a change, the explorer should observe long enough to get the highest and lowest altitudes in the twenty-four hours. He should then proceed in the direction in which the sun's altitude is the lowest, about 34½ miles for each degree of difference in altitude between the highest and lowest points. This should bring him close to the pole.

One application of these curves is the construction of a horizontal sun dial which reads standard time. For the temperate zones, the curves of equal declination are, from the preceding, hyperbolas with the vertices on the meridian. The lines of equal hour-angle are straight lines, and so very easily drawn. For standard time, hour lines are drawn by shifting each point on the hour-angle lines by an amount equal to the longitude correction plus the equation of time when the sun is at that declination. Two sets of hour lines must, therefore, be drawn, one for use in spring and summer, and the other for use in autumn and winter.

UNIVERSITY OF IOWA, FEBRUARY 4, 1932.

Planet Notes for April, 1932

By CLIFFORD E. SMITH

The *Sun* will be moving northeast from the central part of Pisces to the central part of Aries. Its distance from the earth at the beginning of the month will be about 92.8 million miles, and this distance will increase about 750,000 miles during the month. The position of the sun on the first and last days of the month will be, respectively: R.A. $0^h\ 41^m$, Decl. $+4°\ 23'$; R.A. $2^h\ 28^m$, Decl. $+14°\ 38'$.

The phenomena of the *Moon* will occur as follows:

New Moon	April	5 at	7 P.M.	C.S.T.
First Quarter		13 "	9 P.M.	"
Full Moon		20 "	3 P.M.	"
Last Quarter		27 "	9 A.M.	"
Apogee		6 "	12 P.M.	"
Perigee		20 "	2 P.M.	"

Mercury will be in eastern Pisces. At the beginning of the month it will appear about magnitude +3, and it will set about forty minutes after the sun. At the end of the month it will be about first magnitude, and it will rise somewhat more than an hour before the sun. During the beginning and the end of the month the distance of Mercury from the earth will be about 65 million miles; during the middle of the month this distance will be about 10 million miles less. During the beginning and ending of the month the apparent diameter of Mercury will be about 9½ seconds of arc. On April 6 Mercury will be in conjunction with the moon, and on April 21 it will be in conjunction with Mars (Mars ½° S). Inferior conjunction will occur on April 10.

Venus will be an object of about magnitude —4, moving from the western to the eastern part of Taurus, and it will set about three hours after the sun. Its distance from the earth will decrease from about 80 to about 60 million miles and its apparent diameter will increase from about 20 to about 27 seconds of arc. Conjunction with the moon will occur on April 10 (Venus 2° S), and greatest elongation east will occur on April 19 (45° 42′).

Mars will be in Pisces. During this period its distance from the earth will be about 215 million miles, its apparent diameter will be about 4 seconds of arc, and it will rise about an hour before the sun. Conjunction with the moon will occur on April 4, and conjunction with Mercury on April 21 (Mercury ¼° N).

Jupiter will be an evening star of magnitude about —2 in eastern Cancer. The apparent motion of Jupiter in the sky will be westerly until April 8, thereafter easterly. Conjunction with the moon will occur on April 15. During the middle of the month it will be on the meridian about $7^h\ 30^m$ P.M. Standard Time, and, at that time, its distance from the earth will be about 450 million miles, and its apparent diameter will be about 37 seconds of arc.

Saturn will be a morning object in Capricornus of magnitude about +1. During the middle of the month its apparent diameter will be about 15 seconds of arc, and its distance from the earth will be about 950 million miles. On April 24 Saturn will be at quadrature west of the sun, and thus at that time it will be on the meridian about six in the morning. Conjunction with the moon will occur on April 27.

Uranus will be near the sun in apparent position during this period. Conjunction with the sun will occur on April 9.

Neptune will continue in Leo near ρ Leonis, and its apparent motion in the sky will be retrograde. During the middle of the month it will be on the meridian about 9:00 P.M. Standard Time. Its distance from the earth will be about 2750 million miles, and its apparent diameter will be about 2½ seconds of arc. Conjunction with the moon will occur on April 17.

CORRECTIONS. Unfortunately two errors appear in Planet Notes for March in the February issue, one due to the copy and one due to proof-reading. The corrections are: In the third line under *Venus* for *sun* read *earth;* in the third line under *Saturn* after *1000* insert the word *million.*

OCCULTATIONS

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.
(Contributed by the office of the *American Ephemeris.*)

Date 1932	Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION *a* m	IMMERSION *b* m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION *a* m	EMERSION *b* m	EMERSION Angle E from N °
April 9	η Tau	2.9	15 2.3	−0.7	+1.7	83	16 7.2	−0.4	+2.3	224
14	c Gem	5.5	0 10.1	−1.9	−0.5	90	1 23.0	−0.8	−2.5	315
15	γ Cnc	4.7	2 50.1	+0.6	−3.6	175	3 28.0	−2.0	−0.4	243
17	NEPTUNE	7.7	5 3.5	..	..	197	5 22.8	..	..	234
18	83 Leo	6.3	5 18.6	0.0	−2.6	176	6 0.6	−1.4	−1.2	258
18	τ Leo	5.2	5 51.2	−0.3	−2.3	164	6 39.9	−0.9	−1.4	267
20	50 Vir	6.2	1 55.5	−0.7	−0.7	145	3 1.0	−1.5	−0.1	292
21	214 G.Vir	6.5	0 53.7	−1.5	+3.0	65	1 24.1	+0.7	−2.3	2
21	43 H.Vir	5.5	6 45.6	−1.4	−1.1	118	7 56.2	−1.2	−1.5	298
21	231 G.Vir	6.4	7 58.6	−1.1	−1.9	153	8 50.5	−1.0	−1.1	256
21	236 G.Vir	5.7	8 43.1	−1.0	−1.9	144	9 36.6	−0.6	−1.2	260

OCCULTATIONS VISIBLE IN LONGITUDE +91°, LATITUDE +40°.

Date 1932	Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION *a* m	IMMERSION *b* m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION *a* m	EMERSION *b* m	EMERSION Angle E from N °
April 9	η Tau	2.9	14 54.6	+0.2	+1.7	63	15 55.4	−0.2	+1.7	248
11	38 B.Aur	6.5	5 4.2	−0.9	+1.2	24	5 24.4	+1.8	−3.2	340
13	c Gem	5.5	23 34.6	−2.0	−0.9	117	1 1.4	−2.1	−0.8	280
18	80 Leo	6.4	3 19.7	−2.0	−0.3	102	4 24.4	−0.7	−2.2	340
20	50 Vir	6.2	1 58.3	..	..	194	2 23.3	..	..	238
21	43 H.Vir	5.5	6 22.9	−1.1	−1.1	145	7 31.3	−1.9	−0.8	281
21	231 G.Vir	6.4	7 46.0	−0.6	−2.3	176	8 25.6	−2.3	−0.2	244
21	236 G.Vir	5.7	8 27.3	−1.1	−1.9	156	9 21.7	−1.5	−1.0	258
28	128 B.Cap	6.5	10 25.8	−1.8	+1.3	88	11 40.1	−1.5	+1.7	216

OCCULTATIONS VISIBLE IN LONGITUDE +120°, LATITUDE +36°.

April 9	η Tau	2.9	15 3.2	+0.8	+1.6	43	15 49.6	+0.2	+0.9	276
11	38 B.Aur	6.5	4 54.0	−0.4	−1.1	87	5 55.0	+0.2	−1.4	280
18	80 Leo	6.4	2 46.6	−0.6	−1.8	161	3 45.9	−2.0	+0.7	272
20	i Vir	5.7	10 57.3	−1.1	−1.4	113	12 1.3	−0.7	−1.8	303
23	τ Sco	2.8	13 19.8	..	..	156	13 52.9	..	..	212
30	h Aqr	5.4	12 32.0	−0.6	+3.1	6	13 19.5	−1.9	+0.5	291

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated.

The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Request for Photographic Observations of the Moon 1932 March 22

On account of a photometric research I ask that photographic observations of the moon 1932 March 22, both eclipsed and not eclipsed, be sent to the address: Schembor, Vienna XI. Grillgasse 31, III./37, Austria. The method of making the observations is the following: The objective is set in one-third of the focal length. Immediately in front of the film is a diaphragm with an aperture as large as the objective. The diaphragm and the objective are co-axial. I ask that the films with the exposures and not developed be sent to the address above. It is necessary to give the exact time when the exposure was made, the length of the exposure, size of the objective, latitude and longitude of the place of the observation, the distance of the objective from the film during the observation, and condition of the sky. I desire observations of the moon as well at the places where the moon is eclipsed as where the eclipse is invisible.

FREDERICK SCHEMBOR.

Vienna, February 8, 1932.

The Climate of Mars

When thinking of the possibility of life on the other planets we must, first of all, think of the meteorological conditions on their surfaces. By the term "life" we mean the existence of organisms approximately similar to the organisms living on the earth. So, in order to get the faintest notion about the living conditions on the surface of the planet, we must pay attention to the astrophysical study more than to the study of the visible configurations.

The topic of my present article is the conditions on the surface of Mars, if I may be permitted to say so—the climate of Mars.

This planet attracts attention by the interesting configurations on its surface, however little they speak of the possibility of conditions for promoting life. My aim is in a very short article to give a résumé of that little knowledge of the climate of Mars, which astronomy possesses.

The most important argument for the living organism, similar to the earth's organisms, is the atmosphere. Never were there any doubts as to the existence of an atmosphere around Mars. Its composition may be presumed similar to the earth's atmosphere. Moreover, we have some grounds to believe that Martian atmosphere contains relatively more oxygen than the earth's, though the absolute quantity is about 15 per cent normally to the earth's atmosphere. By means of investigation of the photographs of Mars with violet and infra-red light Wright estimates the dimension of Martian atmosphere as 100 kilometers and the pressure as 60 mm. that is close to Lowell's estimate and a little more than that of Adams. It is conformable to the pressure of the atmosphere at 18 kilometers above the earth's surface. In such a pressure water begins to boil at 44° C.

The existence of at least some moisture is evident even from visual observation. Many astronomers observed such formations of light, partly pellucid, matter which may be explained only as clouds. Moreover, the north and south polar

caps with their fast melting in the spring and summer time, and great increasing in the winter time show their watery origin. The spectrographic investigations by Adams and St. John on Mount Wilson in 1925 show the quantity of moisture in Martian atmosphere to be equal to 5-6 per cent of the quantity normal for the earth's atmosphere. It is certainly too little, but however there is not the absolute absence of it.

By means of the observations of the motion of the Martian clouds, Martian winds are noticed. Thus, presuming the composition of the Martian atmosphere to be similar to the earth's, we have found some greatness of pressure of the atmosphere and some quantity of moisture. Now—one of the most important arguments—the temperature on the surface of Mars, that provoked so many disputes in the time when astronomy knew no direct methods for measuring the temperature of the planet's surface. Recently such a method has been found, namely, radiometry with thermocouples. It gave more definite results.

The former opinion of most of the astronomers, that the Martian temperature is exceedingly low, hopelessly low for believing in the existence of live organisms, was confirmed only partly, in the mean temperature. But at the same time, it showed the unexpected increasing of the temperature in certain regions. The results obtained by Coblentz and Lampland at Flagstaff give for the mean Martian temperature —16° C—on the earth +15° C approximately.

But the regional temperatures are more favorable. On the equator at noon +5° C, in the dark regions (so-called seas) up to +10° C and even to +20° C. Towards evening the temperature decreases to zero and after night, in the morning —45° C. Consequently, on the equator, by night, there is always a severe frost. But, in the summer polar regions, in the long permanent polar day, which lasts several months, the temperature keeps at about +18° C. It may be easily explained because the polar regions receive the most continuous radiation.

On the earth we do not find such a condition because of the effect of the extensive atmosphere, which keeps the warmth during the time when the solar radiation is absent—during the night—and, on the other hand, prevents solar radiation in the summer polar regions.

Thus, assuming the sufficient correctness of the above named investigations, we may draw the following conclusions:

1. The pressure of the Martian atmosphere on the surface of the planet is about 60 mm.

2. The composition of the atmosphere is approximately the same as the earth's; the quantity of the oxygen equals 15 per cent of the quantity in the earth's atmosphere, but, as the Martian atmosphere is rarified, we may suppose that the relative quantity of the oxygen is more than in the earth's atmosphere.

3. The quantity of water vapour 5-6 per cent of that normally in the earth's atmosphere.

4. The temperature:

mean	—16° C
on the equator in the day time	+ 5° C
on the equator in the morning	—45° C
on the equator in the dark regions	+10° to +20° C
in the winter polar regions	—70° C
in the summer polar regions	+18° C

The phenomena of the atmosphere resemble the earth's: the winds, the formation of light clouds or mist, hoar frost, etc. Evidently rain is absent. The existence of large ponds or lakes is doubtful. The existence of vegetation, perhaps

very scanty, is evident. The changes of the seasons cause the revival or dying of vegetation just like on the earth's surface, though the development of the spring vegetation begins at high latitudes, contrary to the earth's condition. Perhaps it is caused by the moisture, which during the winter time may gather in high latitudes. In regard to organic life no suggestions can be noticed.

So, as far as our knowledge goes, the Martian climate is very severe. Perhaps too severe for the existence of the highly developed organic creatures. But not at all impossible. Man cannot breathe in an atmosphere of only 60 mm pressure which corresponds to 18 kilometers above the earth's surface. But we know that some of the lower creatures (insects, for instance) can adapt themselves to such conditions. The same applies to the other factors, as temperature, moisture, etc. Mars may possess that life which has adapted itself to the hard Martian conditions. Moreover, the presence of the temporary good temperature conditions, for instance in the summer polar regions, the presence of the vegetation—which is undoubted—may suggest the existence of the more or less developed organisms.

Odessa, April, 1928.

GLEB V. SIMONOW.

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The lack of conspicuous meteor showers in the first few months of the year gives the opportunity for catching up with unpublished data of the previous year. The annual report was also published a month earlier than usual, hence many of our observers did not get their full credits therein. We therefore add a supplement (Table I) to the 1931 report, covering observations received during the past month. It is feared, however, that even yet some observations are not in.

TABLE I.

ADDITIONAL 1931 OBSERVATIONS.

Name	Station	Nights	Meteors
Geddes, M.	New Plymouth, New Zealand	13	502
Greenberg, G.	Lake Worth, Florida	1	36
Hickerson, F.	Webster Groves, Missouri	3	174*
McIntosh, R. A.	Auckland, New Zealand	3	40
Miller, R. W.	Lansdowne, Pennsylvania	4	30
Ridley, G. W.	Alameda, California	1	57
Simpson, W.	Webster Groves, Missouri	6	170*
Williams, J. D.	Tunkhannock, Pennsylvania	4	77
		Total	1086
	TELESCOPIC METEORS.		
Morshead, G. J.	New Plymouth, New Zealand		4
Aldwell, A. B.	San Francisco, California		4
Chandra, R. G.	Jessore, India		13
		Total	21
Additional Perseid Epoch Meteors			52
Additional Fireballs			9
		Total additional data	1168

*Count or largely count.

Meantime we have been reducing radiants and tabulating data as to hourly

rates. Table II contains the latter for some of our most active observers. No radiants are quite ready, as all the results are to be carefully checked.

TABLE II.

GORDON RIDLEY, ALAMEDA, CALIFORNIA.

1931		Began	Ended	Total	Meteors	F.	Rate	Cor.Rate	Remarks
May	15	13:00	14:00	60	4	0.8	4.0	5.0	
	17	9:32	11:32	120	5	1.0	2.5	2.5	
	18	13:11	15:11	120	22	1.0	11.0	11.0	
	19	13:10	14:10	60	5	1.0	5.0	5.0	
	20	13:08	14:08	60	5	1.0	5.0	5.0	
June	6	8:30	10:10	100	4	1.0	2.4	2.4	
	10	13:09	14:09	60	7	1.0	7.0	7.0	
	11	12:58	14:08	70	8	1.0	6.9	6.9	
	28	14:08	15:08	60	6	0.8	6.0	7.5	Moon
	29	14:04	15:14	70	11	0.7	9.4	13.4	Moon

B. C. DARLING, LANSING, MICHIGAN.

1931		Began	Ended	Total	Meteors	F.	Rate	Cor.Rate	Remarks
May	9	9:00	15:06	250	13	0.9	3.2	3.6	
	15	9:02	11:32	150	1	0.8	0.4	0.5	
	16	12:06	14:09	123	4	1.0	2.0	2.0	
	18	9:20	9:58	38	0	0.7	0.0	0.0	
	23	11:35	13:10	95	9	0.9	5.7	6.3	Moon; 1 earlier
	26	9:40	10:15	35	1	0.5	1.7	3.4	Moon
	27	9:27	10:45	61	4	0.7	3.9	5.6	Moon
	31	9:21	10:42	72	0	0.4	0.0	0.0	Moon
June	1	9:32	10:20	48	0	0.8	0.0	0.0	Moon
	5	10:12	12:22	81	6	0.7	4.4	6.3	
	7	9:29	12:07	58	5	0.4	5.2	13.0	
	8	10:15	11:05	50	3	0.9	3.6	4.0	
	10	11:09	12:19	70	8	0.5	6.9	13.8	
	14	10:00	11:00	60	2	0.9	2.0	2.2	
	16	9:57	10:35	38	1	0.8	1.6	2.0	
	19	10:15	13:45	210	16	1.0	4.6	4.6	
	24	13:38	15:30	112	18	1.0	9.6	9.6	From Ann Arbor one earlier

J. D. WILLIAMS, TUNKHANNOCK, PENNSYLVANIA.

1931		Began	Ended	Total	Meteors	F.	Rate	Cor.Rate	Remarks
Sept.	17	12:08	13:26	76	18	0.7	14.2	20.3	
	18	12:30	15:49	138	16	1.0	6.9	6.9	
	20	11:37	13:00	83	10	0.5	7.2	14.4	
	21	13:08	15:00	91	14	1.0	9.2	9.2	
	22	14:26	16:33	99	21	0.7	12.7	18.1	
	23	10:40	11:28	48	1	0.6	1.2	2.0	
Oct.	3	13:56	14:48	52	3	0.9	3.5	3.9	
	4	7:12	12:30	201	22	1.0	6.6	6.6	
	5	9:25	11:14	93	11	1.0	7.1	7.1	
	9	11:05	14:57	194	46	0.9	14.2	15.8	
	10	10:33	12:20	107	23	1.0	12.9	12.9	
		12:59	14:12	73	20	1.0	16.4	16.4	
	11	12:25	14:24	119	36	1.0	18.2	18.2	
		14:40	15:33	53	20	1.0	22.6	22.6	
	12	11:11	14:29	156	38	1.0	14.6	14.6	
	13	11:15	12:22	67	9	0.4	8.1	20.2	
	15	10:06	13:08	104	11	0.3	6.3	[21.0]	
	16	16:40	17:00	20	1	0.6	3.0	5.0	
	18	8:10	12:15	140	14	1.0	6.0	6.0	
		12:17	15:27	144	31	0.9	12.9	14.3	
	19	11:17	16:11	255	58	0.9	13.6	15.1	

1931	Began	Ended	Total	Meteors	F.	Rate	Cor.Rate	Remarks
20	12:02	14:10	121	19	0.9	9.4	10.4	
21	10:18	16:12	301	78	1.0	15.6	15.6	
22	12:25	14:17	96	8	0.9	5.0	5.6	
24	16:08	17:35	82	7	0.5	5.1	10.2	Moon
Nov. 3	17:22	17:51	29	3	0.4	6.2	15.4	
4	11:34	14:40	186	20	0.9	6.5	7.2	
5	11:50	17:39	207	28	0.7	8.1	11.6	
6	12:49	16:47	209	46	1.0	13.2	13.2	
7	11:45	13:07	42	1	0.7	1.4	2.0	
8	11:25	17:45	249	30	0.8	7.2	9.0	
9	11:28	16:31	258	33	1.0	7.7	7.7	
13	12:18	15:43	205	23	1.0	6.7	6.7	
16	7:50	9:08	78	1	0.5	0.8	1.6	

Observations for the 1932 Quadrantid epoch have been reported by S. L. O'Byrne of Webster Groves, Missouri, and by F. K. Smith of Glenolden, Pennsylvania. Both show that the return was a poor one, at least on January 3-4, and less certainly on January 2-3. Further observations of a brilliant fireball that appeared over southern Missouri on January 10, at 9:28 P.M., E.S.T., and of one over Tennessee on February 10, at 7:05 P.M., C.S.T., are much desired.

One of our new but most active members, J. D. Williams, formerly of Tunkhannock, Pennsylvania, has recently moved to Tucson, Arizona, where he plans to do extensive meteor observing. As his records for 1931 are very numerous and excellently made, we trust that with better observing conditions he may have every success in the future.

The writer has been personally informed by Dr. Harlow Shapley that the Harvard expedition to Arizona, which is intensively studying both visual and telescopic meteors, is meeting with great success. Their results will be eagerly awaited and should solve some of our more important problems. Nevertheless the latter are so numerous and so varied that there is and will be plenty of useful work to be done by everyone interested in the subject.

1932 Feb. 20, Flower Observatory, Upper Darby, Pennsylvania.

The Stereographic Projection in Meteor Work

By C. C. WYLIE

The stereographic projection has the property that circles are projected into circles, if the straight line is considered as a special case of the circle. This means, therefore, that if a map of the sky on a stereographic projection is used, the path of a meteor, which is seen as a great circle in the sky, must be either a straight line or an arc of a circle. We have prepared as fundamental a stereographic projection centered on the north celestial pole and extending to 20° south declination. For convenience the scale was taken to agree with the polar charts in Upton's Star Atlas. This means that mimeographed tracings of this star chart can be used for plotting of meteor trails from two or three stations. The meteor trails so plotted can be traced directly on a copy of the fundamental stereographic projection. The altitude and azimuth circles for certain latitudes near 40° are being drawn for the same projection.

RADIANT WORK. At the time of the Perseid and Leonid showers many of the coöperating observers send in plots of the brighter meteor trails observed. The more experienced observers use star charts so that, by right ascension and declina-

tion, the plots are readily transferred to the fundamental stereographic projection. Using a set of great circles intersecting at two points on the celestial equator, and capable of rotation about the celestial pole, each of these meteor trails can be extended back past the area of approximate intersection. The center of this area of approximate intersection is adopted as the radiant.

Occasionally a careful plot in altitude and azimuth is received. The unavoidable errors are, of course, much greater than for meteor trails plotted as seen among the stars. It is, therefore, presumably not worthwhile to transfer the individual meteor trails. None of these plots have as yet been studied, but it is believed that valuable information can be obtained by estimating the altitude and azimuth of the radiant and transferring this to right ascension and declination for comparison with the radiant as obtained by persons plotting on star charts. The length of the average meteor trail can also be compared with the length as drawn by persons plotting on a star chart. It is believed that the information obtained from these plots will be useful in applying systematic corrections to reports on bright fireballs, which are in nearly all cases estimates in altitude and azimuth.

Plots from Two or More Stations. At the time of the Leonid shower in November, 1931, observers from the University of Iowa plotted the paths as seen from three stations, the longest base line being approximately forty miles. Where the same meteor is observed from two stations, the terminal point as seen from each of the two stations, and the point on the horizon of the one station in the direction of the other station must lie on a great circle. The altitude and azimuth lines for the latitude of the first station, together with the direcion of the second station from the first station, make it possible to mark on the fundamental stereographic projection this point on the horizon corresponding to the time of fall of any particular meteor. The terminal points as plotted from the two stations are also transferred to the stereographic chart, and the three points should lie on a great circle. This is quickly tested by rotating the set of great circles about the celestial pole. In this way suspected duplicate meteors are quickly tested. The same test should also hold for the point of beginning, but in general this is not so well observed, as one observer may get his eye on the meteor slightly sooner than the other. If the great circle test for the terminal point is quite satisfactory, the beginning point can be arbitrarily adjusted to meet the conditions by extending one meteor trail backwards or cutting off the other depending on the opinion of the observers. The terminal point of the meteor in the atmosphere is then solved for graphically, by transferring the right ascension and declination as observed from the two stations to altitude and azimuth, and using a map on which the observing stations are marked. The direction in space from which the meteor came is obtained by extending the paths on the stereographic projection, as plotted from the two stations, back to the point of intersection. The terminal point in the atmosphere and this direction together give the actual path through the atmosphere.

The Path of a Bright Fireball. The reports received on a bright fireball are in nearly all cases in altitude and azimuth and usually only approximate. As a starting point for the solution, the most careful estimates from near the actual point of bursting are selected. If possible, use estimates in altitude and azimuth obtained by having experienced persons interview observers, standing exactly where they were when the meteor was seen. Using a map of the vicinity, on which these points of observation can be plotted, and the readings in altitude and azimuth, a solution for the terminal point in the atmosphere is obtained. In addi-

tion to this information from near the point of bursting, there will be in most cases reports from several states. These reports can be sorted out and those which are judged to be the most accurate selected. Some of these will be from experienced observers who have either seen the meteor themselves or carefully interviewed persons who did see the meteor. Extra weight should also be given reports where there is reason to believe that special accuracy has been obtained, as for example, where a meteor was seen to go across the face of the moon, or where the meteor was seen to fall vertically downwards. These reports in altitude and azimuth are transferred to right ascension and declination by the use of altitude and azimuth lines corresponding to approximately the latitude of the observer, and setting the meridian to the right ascension corresponding to the time of fall of the meteor. Theoretically all of these paths when transferred to right ascension and declination should intersect at the same point. The center of the area of approximate intersection is adopted as the right ascension and declination from which the meteor came.

This method of solution is now being developed by Irvin F. Keeler, research assistant, under the direction of the writer.

University of Iowa, February 22, 1932.

Observations of the Leonids at La Plata

The following items concerning the observations of the Leonids were published in the November-December issue of "Revista Astronomica" and were translated and sent to us by Mr. Paul J. Hogan.

With the idea of helping to establish the date of maximum visibility of the Leonids in 1931, Messrs Dawson and Dartayet counted the meteors observed during the mornings of the 13th, 16th, 17th, and 19th of November. As a result of rains on the 14th and 15th, no observations could be made on those days, nor on the 18th because of clouds. On the 20th it was also somewhat cloudy and we were forced eventually to abandon our observations for that morning as conditions showed no signs of improving.

The counts were made at intervals of a half hour, except for the last period of the 13th and the first of the 19th, which were of 20 and 24 minutes respectively. Brilliance was noted in each case, and non-Leonids were noted separately.

Dawson observed all four nights from a place from which the horizon was visible on all sides, situated 1.2 km to the northeast of the Observatory at the extreme south of the canal east of La Plata. Dartayet observed the first two nights from the observatory itself, but with the horizon obstructed by trees to an altitude of 10° or 15°. The other nights he observed at the same place as Dawson, the latter watching the region east and south of Jupiter, which was close to the radiant, while Dartayet concentrated his attention on the region to the north and west. Under these conditions several meteors were noted by both at the same time, especially the very brilliant ones, but were registered by only one of the observers, so that the numbers recorded for these last nights refer to individual meteors, whereas for the first two days it is probable that some of the meteors were recorded by both observers.

In order that no meteors might go uncounted, no effort was made to show the paths of any. But it was noted that the apparent radiant was somewhat to the south and west of the central point, being estimated at $\alpha = 147°$; $\delta = +18°$.

Dawson further observed that several of the meteors recorded on the 16th as not belonging to the Leonids came from a radiant situated in R.A. between

115° and 120° and in Dec. between +15° and +20°. It is probable that this radiant is that of the β Canis Majorids of Denning's catalog.

From the observations it seems to appear that the maximum of activity in the radiant of Leo took place approximately the 17th of November, since, while on the 16th the two observers recorded 11 meteors (some of them probably duplicates) and on the 19th only 5, on the 17th we noted a total of 36 different Leonids, almost all of them of notable brilliance. One of these was as bright as Venus at its maximum. The most brilliant meteors lasted up to 3 seconds and traveled extensive paths, amounting to a quadrant in some cases. All left a luminous trail of a reddish color and the color of the meteors themselves was also reddish in general, although some of them were blue and green.

Once the observations which have been made throughout the world are studied it will be possible to know not only the date but also the exact hour of the maximum activity of this radiant for the present year. The observations made in the Northern Hemisphere will be especially valuable in this respect as conditions for observation of the radiant were more favorable there, due to its north declination.

Comet Notes

By G. VAN BIESBROECK

So far no discoveries of comets have marked the year. A faint object showing unusual motion and a hazy appearance on a plate exposed by K. Reinmuth at Heidelberg (Germany) on 1931 December 31 was thought at first to be of a cometary nature. Subsequent observations at Heidelberg and Williams Bay have shown that the image was that of an asteroid belonging to the interesting family called the Trojan group; its members move in such a way as to make a nearly equilateral triangle with the Sun and Jupiter. The object is now designated as asteroid 1931 YA.

Two of the previously discovered comets are still favorably situated for observation, but their study is limited to larger instruments: Comet 1925 II (Schwassmann-Wachmann) was observed several times by the writer in the beginning of February as a round centrally condensed coma, of total brightness 14^M (February 5-6). During March and April it remains in the constellation of Gemini not far from the bright star Pollux. The ephemeris given on p. 612 of last December's issue is very nearly correct.

In the morning sky Comet 1931 *b* (Nagata) has now again been observed since its conjunction with the Sun, but it is reduced to a very faint circular nebulosity, some 20″ in diameter, with a fairly well defined nucleus. However, the total brightness corresponds to that of a 15^M star (February 12) and this limits the visibility to the more powerful instruments, for which the comet will remain observable for some time.

Unfavorable weather at Williams Bay has largely frustrated the search for the periodic comets expected in the evening sky which were mentioned last month (p. 110). Other stations have apparently not been more successful so far.

In the meantime another short-periodic comet comes under favorable conditions and offers better chances of being recovered: Comet Grigg-Skjellerup which was well observed in 1927 very near to the position predicted by G. Merton.

He had shown that a comet found but poorly observed by Grigg in 1902 and another found by Skjellerup in 1922 were two apparitions of the same object having a period of about five years. With the supposed orbit deduced in 1927 and by taking into account the perturbations by Jupiter during the last five years M. Davidson (*B.A.A. Handbook* for 1932) has established the following ephemeris corresponding to May 18 as the date of perihelion.

EPHEMERIS OF COMET GRIGG-SKJELLERUP.

1932 0^h U.T.		α h m	δ ° ′
March	15	5 36.4	−3 41
	19	5 39.7	2 54
	23	5 44.0	2 4
	27	5 48.9	1 10
	31	5 54.6	−0 14
April	4	6 1.1	+0 41
	8	6 8.1	1 39
	12	6 16.1	2 40
	16	6 24.9	3 40
	20	6 34.8	4 48
	24	6 44.3	6 3
	28	6 55.5	+7 24

The predicted place which is in the constellation of Orion should be quite reliable, but it is harder to foresee the brightness which will almost certainly be quite low in March.

PERIODIC COMET KOPFF also gradually comes under favorable conditions and the search should be started before long by southern observers. The prediction by F. R. Cripps (*B.A.A. Handbook* for 1932) gives August 20 as the most probable date of perihelion passage, and this locates the comet in the constellation of Libra during the month of March.

Williams Bay, Wisconsin, February 23, 1932.

Variable Stars

Monthly Report of the American Association of Variable Star Observers for January, 1932

Somewhat fewer observations are contained in this report than for many months past, but the number of observers and variables observed is not far below normal for winter months. Cloudy weather conditions appear to have prevailed in many parts of the world during December and January.

SS Aurigae was at maximum early in January, and U Geminorum is due to rise during the month of March. SS Cygni was at maximum on January 25, sixty days following the previous maximum. The rise was slow, more than ten days having been occupied in reaching maximum brightness.

The R Coronae Borealis type variables all require special attention; R Cor Bor itself because it has not decreased appreciably in brightness for more than seven years. SU Tauri has at last reached normal maximum brightness, magnitude 9.5. S Apodis passed through a shallow minimum recently, attaining magnitude 11.6 only. On previous occasions it has dropped to magnitude 14 or fainter. RY

Variable Star Observations Received During January, 1932.

Nov. 0 = J.D. 2426646; Dec. 0 = J.D. 2426676; Jan. 0 = J.D. 2426707.

J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
V Scl	T Cas	RW And	S Psc	U Per	o Cet
000339	001755	004132	011208	015254	*021403*
676 12.6 Bl	709 8.9 Mc	692 10.8 Th	685 13.9 L	678 8.1 Jo	691 9.3 Bo
S Scl	718 9.0 Pt	705 9.3 Jo	S Cas	681 8.4 Jo	691 9.2 Wd
001032	R And	706 9.9 Th	011272	687 8.5 Ry	696 9.2 Jo
571 10.5 Kd	001838	710 9.6 Hl	677 8.8 Jo	690 7.7 Bo	702 9.2 Wd
623 7.6 Kd	647 11.5 Kd	713 9.4 Hl	679 8.7 Jo	691 7.6 Bo	703 9.0 Cy
625 7.6 Kd	681 9.8 Gy	V And	686 8.7 Jo	692 8.3 Jo	703 9.4 Jo
646 7.6 Kd	683 9.7 Ah	004435	691 8.9 Bc	704 8.7 Ry	705 9.2 Sf
652 7.5 Kd	684 10.0 Jo	685 14.0 L	692 8.6 Jo	706 8.6 B	706 9.2 Wd
655 7.5 Kd	686 9.9 Jo	706 12.1 B	692 9.2 Th	709 8.6 Bo	**718 9.0 Pt**
675 7.9 En	691 9.6 Hu	X Scl	697 9.3 Wy	714 9.3 Bw	720 9.2 Bo
676 8.5 Bl	691 9.7 Wd	*004435*	703 9.3 Wy	718 9.5 Pt	732 8.8 Cy
678 7.7 Kd	705 8.2 Jo	676[13.6 Bl	705 8.4 Jo	720 8.8 Bo	S Per
679 7.9 Kd	718 7.2 Pt	RV Cas	706 9.5 Th	S Ari	021558
681 8.2 Kd	720 7.0 Ma	004746a	U Psc	015912	678 9.1 Jo
692 8.8 Kd	S Tuc	718 9.3 Pt	011712	685 14.3 L	681 9.4 Jo
T Cet	*001862*	— Cas	685 14.1 L	687[13.7 Br	688 9.3 Jo
001620	676[13.2 Bl	004746b	718 14.2 Pt	R Ari	691 10.0 Bo
564 6.2 Kd	S Cet	718 10.9 Pt	R Scl	021024	692 9.6 Jo
572 6.2 Kd	*001909*	W Cas	*012233a*	672 8.8 C	704 9.8 B
590 6.3 Kd	678 9.0 Jo	004958	565 8.6 Kd	672 8.7 Pk	718 9.5 Pt
623 6.7 Kd	681 9.4 Jo	677 10.0 Jo	571 8.6 Kd	685 10.5 L	720 9.7 Bo
625 6.4 Kd	684 9.6 Jo	684 10.0 Jo	647 8.6 Kd	686 10.5 Ah	R Cet
646 6.5 Kd	685 9.8 Mp	686 9.9 Jo	652 8.5 Kd	692 9.7 L	*022000*
652 6.7 Kd	687 10.2 Br	690 10.2 Bo	656 8.6 Kd	718 9.8 Pt	678 8.4 Jo
656 6.7 Kd	690 10.2 L	691 10.3 Bo	679 7.9 Kd	720 9.1 Ma	684 8.3 Jo
679 6.3 Kd	691 11.0 Bc	692 9.5 Jo	681 7.9 Kd	W And	685 8.1 L
681 6.5 Kd	691 10.0 Hu	704 9.4 B	RZ Per	021143a	**692** 8.2 L
687 6.3 L	692 9.9 Jo	709 9.9 Bo	012350	706 13.4 B	**703** 8.7 Jo
T And	696 10.6 Jo	714 10.5 Bw	685 9.3 Mp	718 12.6 Pt	**705** 8.9 Sf
001726	703 11.7 Sf	718 9.8 Pt	686 9.6 L	T Per	RR Per
647 9.2 Kd	704 11.7 Jo	720 9.7 Bo	706 9.3 B	021258	022150
677 8.1 Jo	718 12.6 Pt	U Tuc	R Psc	678 8.5 Jo	686 11.6 L
681 7.7 Gy	T Phe	*005475*	012502	681 8.6 Jo	R For
686 8.3 Jo	*002546*	657 8.6 Sl	718 11.6 Pt	688 8.5 Jo	*022426*
691 8.5 Jo	674 12.0 En	674 8.9 En	RU And	691 8.6 Bo	673 10.1 Bl
691 9.0 Hu	676 11.5 Bl	676 8.6 En	013238	692 8.5 Jo	676 10.2 Bl
692 8.9 Th	W Scl	676 8.4 Bl	687 13.5 L	718 8.8 Pt	U Cet
704 9.4 B	*002833*	691 8.4 Sl	706 14.0 B	720 9.0 Bo	*022813*
706 9.6 Th	676 13.0 Bl	Z Cet	720[13.9 Ma	Z Cep	679 7.0 Jo
710 9.7 Hl	α Cas	*010102*	Y And	021281	**681** 7.1 Gy
713 9.9 Hl	003656	685 8.8 L	013338	694[12.5 Mp	685 7.1 L
718 9.8 Pt	636 2.3 Oy	692 9.1 L	687 14.5 L	o Cet	705 7.9 Jo
T Cas	690 2.5 Oy	718 9.7 Pt	718 11.3 Pt	*021403*	718 8.4 Pt
001755	U Cas	U Scl	720 10.3 Ma	564 6.4 Kd	720 8.5 Bo
677 8.6 Jo	004047a	*010630*	X Cas	565 6.7 Kd	RR Cep
678 9.1 Mn	650 9.2 Hi	676[13.2 Bl	014958	664 8.7 Sl	022980
684 8.9 Mn	675 9.5 Hi	U And	678 10.0 Jo	674 8.8 Sl	694 12.7 Mp
685 8.1 Mp	686 9.7 L	010940	684 10.0 Jo	674 9.0 En	R Tri
686 8.6 Jo	691 9.9 Hu	686 10.5 L	686 9.9 Jo	678 9.0 Jo	023133
686 8.6 L	705 11.4 Sf	691 10.4 Hu	692 10.5 Jo	678 9.6 Mn	**572** 8.7 Kd
690 9.0 Mn	705 11.1 B	UZ And	694 10.9 Mp	681 9.3 Gy	**623** 9.8 Kd
692 8.6 Th	710 11.4 Hl	011041	705 10.8 Jo	684 9.1 Jo	**626** 9.8 Kd
692 8.8 Jo	718 12.6 Pt	687 12.3 L	706 11.9 Bn	684 9.6 Mn	**647** 11.2 Kd
695 8.7 Jo	RW And	706 12.6 B	718 12.3 Bn	685 9.2 L	**652** 11.5 Kd
705 8.9 Mn	004132	714 12.9 Bw	718 12.0 Pt	686 9.2 Cy	**672** 9.9 C
706 8.6 Th	684 12.4 Jo	720 13.0 Ma		689 9.5 Cy	**672** 9.9 Pk
707 9.0 Mc	686 11.9 Jo			691 8.8 Sl	**679** 11.7 Kd

VARIABLE STAR OBSERVATIONS RECEIVED DURING JANUARY, 1932.

J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
R TRI	X CET	T CAM	R LEP	S AUR	S CAM
023133	*031401*	043065	*045514*	052034	053068
680 11.7 Kd	692 9.9 Jo	704 10.0 Jo	674 6.5 Sl	678 9.3 Jo	678 8.5 Jo
681 11.5 Jo	703 10.5 Jo	718 11.8 Pt	677 7.0 Jo	684 9.8 Jo	681 8.3 Jo
681 12.0 Gy	705 10.2 Sf	720 10.8 Bo	686 7.2 Jo	688 9.9 Jo	684 8.4 Jo
693 11.0 Jo	718 11.5 Pt	RX TAU	688 7.3 Jo	691 9.9 Jo	688 8.3 Jo
702 11.2 Sf	Y PER	043208	690 7.2 L	691 10.0 Bo	704 8.1 Jo
704 10.3 Jo	032043	690 13.7 L	691 6.2 Sl	693 9.4 B	718 9.1 Pt
718 9.9 Pt	678 10.2 Jo	706 13.7 B	691 6.6 Bc	695 9.8 Jo	720 8.8 Bo
720 9.6 Ma	681 10.3 Jo	R RET	692 7.2 Jo	703 9.9 Jo	RR TAU
720 9.6 Gy	684 10.4 Jo	*043263*	703 7.0 Jo	709 10.4 Mc	053326
721 9.6 Sf	688 10.5 Jo	654 7.5 En	718 7.0 Pt	720 11.3 Bo	680 10.7 L
T ARI	691 10.7 Bo	657 7.3 Sl	720 7.3 Ma	W AUR	685 10.7 L
024217	693 10.6 Jo	674 7.5 Sl	V ORI	052036	686 10.6 L
672 10.6 C	704 10.5 Jo	675 7.8 En	050003	678 9.6 Jo	690 10.7 L
672 10.6 Pk	718 9.9 Pt	676 8.0 Bl	685 14.3 L	684 8.6 Jo	693 10.6 B
679 9.7 Jo	720 9.5 Bo	691 8.4 Sl	706 14.1 B	686 8.7 L	694 10.7 L
684 9.6 Jo	R PER	X CAM	718 13.0 Pt	688 8.0 Jo	703 10.6 Al
693 9.7 Jo	032335	043274	T LEP	691 8.2 Jo	706 10.6 B
704 10.5 Jo	678 9.0 Jo	678 8.0 Jo	*050022*	695 8.3 Jo	708 10.7 Br
W PER	681 9.4 Jo	681 8.0 Jo	676 10.2 Bl	703 8.2 Jo	RU AUR
024356	685 10.3 L	686 8.1 Jo	677 10.6 Jo	703 8.8 Sf	053337
678 10.6 Jo	688 9.5 Jo	686 7.8 L	686 10.4 Jo	713 9.1 Hl	692 10.5 Sf
681 10.9 Jo	718 11.1 Pt	692 8.3 Jo	688 10.7 Jo	718 8.8 Pt	703 11.0 Wy
684 11.2 Jo	720 12.4 Ma	718 8.9 Pt	692 9.7 Jo	720 8.7 Ma	705 11.0 Sf
686 10.4 Cy	NOV PER	721 9.3 Bg	703 8.8 Jo	721 9.0 Sf	718 11.7 Pt
687 10.8 Ry	032443	R DOR	718 9.0 Pt	S ORI	U AUR
688 10.8 Jo	718 13.2 Pt	*043562*	S PIC	*052404*	053531
691 10.5 Cy	T FOR	654 5.2 En	*050848*	703 11.3 Wy	685 14.1 L
693 10.8 Jo	*032528*	657 5.2 Sl	657 12.2 En	703 10.7 Al	704 13.7 B
694 10.7 Cy	685 8.8 L	674 5.3 Sl	676 13.4 Bl	709 11.4 Wy	718 13.0 Pt
703 11.0 Cy	R TAU	675 5.3 En	R AUR	709 10.3 B	Y TAU
704 10.8 Ry	042209	676 5.5 Bl	050953	718 11.8 Pt	053920
704 10.8 Jo	718 13.2 Pt	691 5.2 Sl	678 7.6 Mn	720 11.6 Ma	679 7.5 Mn
710 10.4 Hl	720 12.2 Ma	R CAE	678 7.5 Jo	T ORI	684 7.4 Mn
714 10.3 Bw	W TAU	*043738*	684 7.6 Jo	*053005a*	690 7.3 Mn
718 10.5 Pt	042215	657 8.2 En	684 7.8 Mn	677 10.7 Jo	SU TAU
720 10.7 Cy	678 10.6 Jo	662 8.3 En	688 7.7 Jo	684 10.8 Jo	054319
732 10.7 Cy	681 10.7 Jo	675 9.0 En	690 8.0 Mn	685 10.8 L	685 9.6 L
R HOR	685 10.4 L	676 8.4 Bl	695 7.8 Jo	686 10.2 L	690 9.5 L
025050	686 10.1 Jo	R PIC	696 8.2 Ah	686 11.0 Jo	690 9.6 Pt
657 11.2 Sl	691 10.1 Cy	*044349*	703 8.1 Jo	688 11.0 Jo	691 9.6 Pt
662 12.3 En	692 10.4 Jo	657 7.0 En	705 8.2 Jo	690 10.4 L	692 9.6 Pt
673 12.5 Bl	694 10.3 Cy	675 7.7 En	705 8.4 Mn	690 10.4 Pt	693 9.6 Pt
675 12.2 En	703 10.4 Jo	676 7.5 Bl	718 8.6 Pt	691 10.5 Jo	694 9.5 L
691 12.5 Sl	718 10.1 Pt	V TAU	T PIC	692 10.5 Jo	702 9.6 Pt
T HOR	720 10.5 Cy	044617	*051247*	693 10.6 Pt	713 9.6 Pt
025751	732 10.2 Cy	706 13.9 B	657 9.0 En	703 10.7 Jo	714 9.6 Pt
657 13.1 Sl	S TAU	717 13.1 Bg	675 9.8 En	709 10.2 B	715 9.6 Pt
676 13.0 Bl	042309	721 13.1 Bg	676 10.0 Bl	710 10.0 Me	718 9.6 Pt
691 11.7 Sl	718 14.0 Pt	R ORI	NOV TAU	714 10.6 Bw	720 9.5 Ma
U ARI	720 14.4 Ma	045307	051316	714 10.5 Pt	S COL
030514	T CAM	676 9.2 B	690 14.7 L	715 10.6 Pt	*054331*
686 14.1 L	043065	686 9.2 L	T COL	716 10.6 Pt	657 12.2 En
X CET	678 9.0 Jo	692 9.8 Sf	*051533*	719 10.2 Wy	675 12.6 En
031401	681 9.5 Jo	705 10.0 Sf	657 10.0 En	720 10.0 Ma	676 13.0 Bl
678 8.5 Jo	684 9.7 Jo	721 10.2 Sf	675 10.9 En	AN ORI	Z TAU
684 9.4 Jo	686 9.6 L	R LEP	676 10.4 Bl	*053005f*	054615a
685 9.1 L	688 9.8 Jo	*045514*		720 10.9 Ma	685 12.3 L
692 9.7 L	691 10.0 Bo	657 6.7 Sl			720 12.9 Ma

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J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
RU TAU	Z AUR	X MON	L_2 PUP	R CHA	R LEO
054615c	055353	*065208*	*071044*	*082476*	094211
685 13.2 L	695 9.8 Jo	680 8.4 L	691 4.3 Sl	657 8.2 Sl	686 9.0 Jo
720 13.9 Ma	698 10.2 Pt	690 8.0 L	RR MON	674 9.0 Sl	688 8.8 Jo
R COL	702 10.2 Pt	R LYN	071201	675 9.9 En	689 9.0 Pt
054629	703 9.6 Jo	065355	652[13.0 Kd	676 9.4 Bl	692 8.7 Jo
657 11.6 En	703 10.1 Wy	678 9.8 Mn	685[14.2 L	691 9.7 Sl	696 8.6 Ah
675 12.0 En	703 9.6 Sf	680 9.8 L	V GEM	U CNC	704 8.9 Wd
676 12.2 Bl	707 10.3 Mc	684 9.9 Mn	071713	083019	704 8.6 Jo
α ORI	713 10.2 Pt	690 10.0 Mn	686 9.2 L	689 13.4 L	720 7.8 Ma
054907	714 10.2 Pt	691 9.7 L	689 9.2 Pt	720[13.9 Ma	L CAR
674 0.3 Sl	715 10.2 Pt	720 10.7 Ma	703 8.7 Al	S HYA	*094262*
690 0.8 Oy	718 10.2 Pt	RS GEM	S CMI	084803	674 3.8 Sl
691 0.1 Sl	721 10.4 Sf	065530	072708	689 12.0 Pt	691 4.0 Sl
703 0.5 Mc	R OCT	720 12.0 Ma	677 9.7 Jo	T HYA	Z VEL
707 0.5 Mc	*055686*	Z CMA	681 11.4 Mu	*085008*	*094053*
U ORI	657 9.9 Sl	*065911*	684 10.4 Jo	685 7.7 L	676 12.0 Bl
054920a	674 10.3 Sl	674 9.3 Sl	688 10.7 Jo	689 7.6 Pt	V LEO
623 8.7 Kd	676 10.4 Bl	691 9.6 Sl	689 11.0 Pt	T CNC	095421
653 6.9 Kd	X AUR	V CMI	S VOL	085120	689 12.6 Pt
656 6.8 Kd	060450	070109	*073173*	681 8.0 Jo	720[12.8 Cy
679 6.8 Kd	686 9.6 L	685 10.9 L	676[13.2 Bl	686 8.0 Jo	721[13.5 Ma
679 6.0 Mn	696 9.7 Jo	688 11.3 Jo	U CMI	689 8.0 Pt	RV CAR
679 5.7 Jo	703 9.0 Sf	689 11.3 Pt	073508	695 8.1 Jo	*095563*
681 6.9 Kd	708 8.3 B	705 12.0 Jo	695 8.1 Jo	704 8.0 Jo	676[13.1 Bl
684 5.8 Jo	718 8.3 Pt	R GEM	704 8.0 Jo	T PYX	S CAR
684 6.0 Mn	721 8.6 Sf	070122a	677 9.8 Jo	*090031*	*100661*
688 5.8 Jo	V AUR	677 7.0 Jo	680 9.5 L	676 [8 Bl	674 6.4 Sl
690 6.6 Mn	061647	679 7.3 Mn	684 9.5 Jo	V UMA	676 6.7 Bl
691 5.6 Sl	689 12.2 L	684 7.4 Mn	688 9.0 Jo	090151	691 6.1 Sl
691 6.2 Wd	V MON	684 6.9 Jo	689 9.5 Pt	U UMA	U UMA
692 6.9 Kd	*061702*	686 6.7 Jo	690 8.7 L	090425	100860
695 5.9 Jo	718 12.4 Pt	689 6.5 Pt	704 8.5 Jo	W CNC	678 6.6 Mn
696 6.5 Ah	AG AUR	*074241*	W PUP	090425	684 6.8 Mn
702 6.6 Wd	062047	676 10.5 Bl	676 10.5 Bl	T GEM	690 6.7 Mn
703 6.3 Jo	678 9.5 Mn	691 6.2 Wd	074323	689 13.2 L	Z CAR
703 7.0 Mc	684 9.6 Mn	696 7.0 Ah	689 11.3 Pt	720[12.8 Cy	*101058a*
704 7.0 Wd	686 9.7 L	702 6.6 Wd	720 13.3 Ma	RX UMA	676[12.6 Bl
705 6.4 Jo	690 9.8 Mn	703 6.7 Jo	R CNC	685 11.2 L	W VEL
706 6.8 Wd	705 10.1 Mn	703 7.2 Al	081112	RW CAR	*101153*
707 7.0 Mc	NOV PIC	704 6.8 Wd	*091868*	*091868*	676 12.6 Bl
709 7.0 Mc	*063462*	705 7.0 Mn	688 10.8 Jo	676[12.8 Bl	U HYA
710 6.6 GD	654 8.4 En	706 6.6 Wd	689 11.6 Pt	Y VEL	*103212*
718 7.0 Pt	672 8.4 En	Z GEM	692 10.7 Jo	*092551*	656 6.0 Kd
V CAM	S LYN	070122b	704 10.5 Jo	676 11.5 Bl	663 6.0 Kd
054974	063558	689 12.6 Pt	720 10.3 Cy	R CAR	R UMA
687 11.0 L	680 12.9 L	TW GEM	732 10.0 Cy	*092962*	103769
703 11.5 Sf	691 13.5 L	070122c	V CNC	674 8.5 Sl	681 12.2 Gy
705 11.0 B	709 13.8 B	689 8.0 Pt	081617	676 8.9 Bl	689 12.1 Pt
709 11.1 B	718 13.6 Pt	R CMI	681 9.2 Gy	691 8.9 Sl	691 11.7 Wd
718 11.7 Pt	X GEM	070310	689 9.6 Pt	X HYA	704 11.7 Wd
Z AUR	064030	677 11.2 Jo	689 9.5 L	*093014*	720 12.6 Cy
055353	706 12.3 Bn	685 11.0 L	720 11.8 Cy	720 9.7 Gy	V HYA
678 9.9 Jo	715 12.3 Bn	688 11.0 Jo	720 11.8 Gy	Y DRA	*104620*
684 9.9 Jo	720 12.4 Bn	689 11.7 Pt	732 12.2 Cy	093178	680 6.6 L
688 9.8 Jo	720 12.9 Ma	703 11.0 Al	RT HYA	686 13.7 L	689 6.3 Pt
690 10.2 Pt	Y MON	704 11.0 Jo	*082405*	R LMI	690 6.8 L
691 10.2 Pt	065111	L_2 PUP	680 9.0 L	093934	W LEO
692 10.1 Pt	690 14.0 L	*071044*	689 8.5 Pt	681 11.8 Gy	104814
694 10.0 Pt	720 13.9 Ma	657 4.1 Sl	690 8.4 L	689 11.9 Pt	680 12.2 L
		674 3.9 Sl	707 8.0 Th		

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J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
W LEO	T UMA	R CVN	Y LIB	R CRB	U HER
104814	123160	134440	*150605*	154428	162119
690 14.0 L	720 10.5 Gy	713 8.5 Pt	677 9.6 L	693 6.0 Cy	647 11.5 Hi
RS CAR	R VIR	720 8.3 Gy	689 10.1 L	693 6.0 L	702 7.4 Sh
110361	123307	T APS	713 12.4 Pt	694 6.0 L	707 7.4 Sh
691[12.3 Sl	689 7.0 Pt	*134677*	S LIB	694 6.0 Cy	720 8.7 Gy
S LEO	RS UMA	672 12.9 Bl	*151520*	698 5.9 Cy	SS HER
110506	123459	Z BOO	686 8.5 L	701 5.9 Cy	162807
680 11.0 L	681[11.8 Gy	140113	S SER	701 6.0 Me	686 12.4 L
689 11.1 Pt	689 14.1 Pt	680 12.0 L	151714	702 5.9 Cy	713 8.4 Pt
690 9.9 L	693 13.7 Ry	692 10.9 L	693 10.8 L	702 6.0 Sh	W HER
RY CAR	706[13.2 Bn	Z VIR	S CRB	705 5.9 Me	163137
111561	720[12.6 Cy	*140512*	151731	713 6.1 Pt	689 13.0 Pt
676[13.1 Bl	S UMA	685 12.7 L	571 10.9 Kd	717 6.0 Cy	R UMI
RS CEN	123961	U UMI	651 6.7 Ko	718 5.9 Cy	163172
111661	677 12.0 Jo	141567	679 7.0 Mn	720 5.9 Cy	677 10.3 Jo
676 9.2 Bl	681 11.4 Gy	686 11.0 Jo	715 8.3 Pt	720 6.0 Gy	678 10.3 Jo
W CEN	686 11.8 Jo	688 10.8 Jo	RS LIB	722 5.9 Cy	681 10.4 Jo
115058	689 11.9 Pt	692 10.7 Jo	*151822*	724 5.9 Cy	684 10.5 Jo
676 9.3 Bl	691 11.5 Jo	713 10.8 Pt	689 7.6 L	X CRB	686 10.3 L
SU VIR	704 9.7 Wd	S BOO	RU LIB	154536	688 10.6 Jo
120012	705 10.2 Jo	141954	*152714*	694 13.3 L	703 10.4 Jo
680 10.0 L	706 9.5 Sh	686 13.2 L	686 9.3 L	R SER	705 10.2 Jo
689 9.3 Pt	706 9.8 Wd	713[12.4 Pt	713 9.6 Pt	154615	R DRA
693 10.4 L	710 9.4 Sh	*720*[12.0 Gy	S UMI	713 7.2 Pt	163266
T VIR	720 8.9 Gy	RS VIR	153378	V CRB	678 12.5 Jo
120905	RU VIR	142205	681 11.6 Gy	154639	681 12.3 Jo
680 10.0 L	124204	680 9.9 L	683 10.8 Ko	646 9.0 Hi	681 11.7 Gy
689 9.9 Pt	685 13.5 L	693 10.1 L	688 11.0 Jo	713 8.6 Pt	688 12.2 Jo
690 10.0 L	U VIR	V BOO	692 11.2 Jo	724 10.0 Cy	689 11.9 Pt
R CRV	124606	142539a	713 11.7 Pt	Z CRB	702 10.6 Wd
121118	685 13.2 L	557 8.6 Kd	720 11.8 Gy	155229	703 12.0 Jo
680 11.2 L	713 11.1 Pt	572 8.8 Kd	R CRB	686 9.5 L	705 12.0 Jo
693 12.4 L	RV VIR	581 8.8 Kd	154428	RZ SCO	720 11.2 Gy
SS VIR	*130212*	590 8.9 Kd	556 6.0 Kd	*155823*	S HER
122001	685[13.8 L	692 9.8 Jo	561 6.2 Kd	713 10.6 Pt	164715
680 7.8 L	U OCT	713 8.9 Pt	563 6.3 Kd	R HER	689 12.2 Pt
690 7.8 L	*131283*	724 9.6 Cy	569 6.2 Kd	160118	RV HER
T CVN	672 9.2 Bl	R CAM	571 6.3 Kd	651 9.0 Ko	165631
122532	V CVN	142584	575 6.3 Kd	652 9.0 Ko	678 10.2 Jo
689 11.1 Pt	131546	647[11.2 Hi	590 6.0 Kd	713 10.6 Pt	681 10.1 Jo
Y VIR	710 7.3 GD	707 8.8 Th	595 6.2 Kd	720 9.4 Gy	684 10.0 Jo
122803	V VIR	R BOO	611 6.2 Kd	U SER	686 9.9 Jo
693 13.6 L	*132202*	143227	622 6.1 Kd	160210	686 9.9 L
T UMA	685 11.1 L	713 10.1 Pt	624 6.0 Kd	628 8.8 Hl	689 10.5 Pt
123160	R HYA	V LIB	628 6.0 Kd	713 12.0 Pt	698 10.3 L
677 7.8 Jo	*132422*	*143417*	629 6.1 Oy	724[12.0 Cy	RT HER
678 8.1 Mn	685 8.8 L	685 9.9 L	642 6.2 Kd	SX HER	170627
681 8.7 Gy	713 8.2 Pt	S APS	646 6.2 Kd	160325	644 11.0 Hi
684 8.5 Mn	S VIR	*145071*	651 6.0 Ko	686 8.5 L	689 12.5 Pt
686 8.4 Jo	*132706*	657 10.8 En	652 6.0 Kd	713 8.0 Pt	RW SCO
686 8.6 Ah	713 12.0 Pt	673 10.8 Bl	679 5.8 Mn	RU HER	*170833*
689 8.9 Pt	T UMI	674 10.8 Bl	680 6.0 L	160625	657 10.0 En
690 8.9 Mn	133273	RT LIB	685 6.0 L	686 13.5 L	Z OPH
691 8.6 Jo	688 12.0 Jo	*150018*	686 6.0 L	W CRB	171401
696 9.1 Ah	691 12.9 L	713 12.5 Pt	689 6.0 L	161138	713 10.7 Pt
704 9.7 Wd	692 11.7 Jo	T LIB	690 6.0 Cy	689 11.9 Pt	RS HER
704 9.8 Gy	R CVN	*150510*	690 6.0 Sh	V OPH	171723
705 9.7 Jo	134440	689[12.0 L	691 5.9 Cy	*162112*	677 8.5 Jo
706 9.9 Wd	696 9.0 Ah		692 5.9 Cy	713 8.5 Pt	681 8.4 Jo

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J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
RS HER	X DRA	R SCT	R CRA	RY SGR	R CYG
171723	180666	*184205*	*185537a*	*191033*	193449
684 8.3 Jo	686 11.7 L	571 5.5 Kd	674 12.5 En	654 11.0 En	702 8.9 Wd
686 8.2 Jo	687 11.6 Br	575 5.7 Kd	T CRA	657 10.9 En	703 8.6 Jo
689 8.5 Pt	689 10.2 Pt	589 5.5 Kd	*185537b*	657 10.6 Sl	703 9.7 Mc
S OCT	720 11.0 Gy	595 5.5 Kd	657 12.8 En	662 10.3 En	705 8.7 Jo
172486	TV HER	597 5.5 Kd	657 12.8 Sl	672 9.0 En	704 9.4 Gy
674 12.4 Bl	181031	611 5.7 Kd	Z LYR	674 9.1 Bl	707 9.8 Mc
RU OPH	686 9.6 L	622 6.5 Kd	185634	674 10.3 Sl	709 9.9 Mc
172809	698 10.0 L	624 6.6 Kd	686 14.1 L	675 9.0 Bl	RV AQL
687 8.6 L	RY OPH	628 6.7 Kd	RT LYR	TY SGR	193509
689 8.6 Pt	181103	637 6.8 Kd	185737	*191124*	689 9.9 Pt
720 9.7 Gy	689 8.5 Pt	642 6.2 Kd	686 13.3 L	657 11.7 En	689 10.5 L
RU SCO	702 10.6 Wd	646 5.9 Kd	698 12.4 L	674 10.9 En	T PAV
173543	W LYR	652 5.8 Kd	V AQL	675 10.9 Bl	*193972*
657 9.5 En	181136	653 5.9 Kd	*185905*	S SGR	674 12.7 En
674 9.3 Bl	686 12.5 Jo	655 5.7 Kd	684 7.8 Mn	*191319a*	675 12.8 Bl
SV SCO	686 12.5 L	656 5.8 Sl	690 7.7 Mn	657 10.7 En	RT CYG
174135	688 12.3 Jo	677 5.0 Bf	R AQL	674 11.1 En	194048
674[11.0 Bl	689 12.3 Pt	677 5.5 Bc	190108	675 11.0 Bl	677 8.5 Jo
W PAV	696 12.0 Jo	678 5.8 Bc	649 6.0 Ko	Z SGR	681 8.3 Jo
174162	703 11.6 Jo	678 5.7 Bf	679 7.7 Mn	*191321*	681 7.8 Gy
654[12.3 En	705 11.0 Jo	678 5.5 Jo	684 7.4 Mn	657 10.6 En	684 8.0 Jo
674[12.3 Bl	RV SGR	679 5.7 Bc	689 7.0 Pt	SW SGR	686 7.5 Ah
U ARA	*182133*	680 5.7 Kd	690 7.5 Mn	*191331*	688 7.8 Jo
174551	657 12.8 En	681 5.4 Jo	696 7.9 Ah	675[12.1 Bl	689 7.8 Pt
660[12.3 En	674 12.2 Bl	682 5.8 Kd	RX SGR	TZ CYG	691 7.5 Jo
RY HER	SV DRA	683 5.8 Bc	*190818*	191350	691 8.0 GC
175519	183149	684 5.8 Mn	657[12.4 En	689[10.3 Pt	695 7.3 Jo
687 11.9 L	687 13.8 L	684 5.9 Jo	RW SGR	U LYR	696 7.2 Ah
689 12.2 Pt	RZ HER	686 6.0 Jo	*190819a*	191637	702 6.9 Wd
V DRA	183225	687 5.2 L	657 9.1 En	678 8.7 Jo	703 7.9 Mc
175654	689 12.2 L	691 5.7 Pt	TY AQL	681 8.8 Jo	703 7.0 Jo
686 12.5 L	698 12.1 L	691 6.0 Bc	*190907*	684 8.9 Jo	705 6.8 Jo
689 12.1 Pt	X OPH	691 6.0 Cy	689 10.3 Pt	688 9.1 Jo	706 7.0 Wd
R PAV	183308	692 6.0 Bf	S LYR	689 9.7 Pt	707 7.6 Mc
180363	557 8.1 Kd	692 5.9 Bc	190925	691 9.2 Jo	709 7.7 Mc
654 9.4 En	561 8.4 Kd	693 6.0 Bc	689 14.1 L	703 9.6 Jo	TU CYG
660 9.8 En	565 8.2 Kd	693 6.0 Bf	X LYR	AF CYG	194348
674 11.0 En	572 8.4 Kd	694 5.8 Pt	190926	192745	691 13.5 L
T HER	651 8.6 Ko	698 5.6 L	689 9.0 Pt	686 7.0 Ah	696 12.5 Jo
180531	677 8.3 Jo	NOV AQL	RS LYR	696 7.0 Ah	703 12.0 Jo
625 11.5 Kd	679 8.4 Jo	184300	190933a	TY CYG	705 11.5 Jo
678 8.2 Jo	679 8.3 Mn	691 11.5 Pt	681 11.4 Gy	192928	X AQL
681 8.3 Jo	681 8.5 Jo	R LYR	686 11.3 L	689 13.3 L	194604
684 8.3 Jo	684 8.6 Jo	185243	689 11.4 Pt	RT AQL	644 9.7 Hi
686 8.2 L	686 8.5 Jo	690 4.1 Oy	698 11.2 L	193311	662 10.8 Hi
688 8.5 Jo	687 8.6 L	S CRA	720 11.3 Gy	689 13.0 Pt	675 11.1 Hi
689 8.4 Pt	689 8.6 Pt	*185437a*	U DRA	R CYG	689 12.2 Pt
696 8.7 Jo	698 8.2 L	654 12.0 En	190967	193449	689 11.8 L
696 8.6 Ah	RY LYR	657 11.6 En	686 12.7 L	677 7.8 Jo	χ CYG
698 8.9 L	184134	657 11.9 Sl	689 12.4 Pt	681 8.2 Jo	194632
720 11.0 Gy	689 13.5 L	674 12.5 Sl	R SGR	681 8.8 Gy	556 8.6 Kd
W DRA	R SCT	674 12.5 En	*191019*	684 8.4 Jo	561 8.5 Kd
180565	*184205*	R CRA	651 9.0 Ko	686 8.4 Ah	569 8.0 Kd
686 11.8 L	556 5.7 Kd	*185537a*	657 9.0 En	688 8.4 Jo	575 7.0 Kd
689 10.9 Pt	561 5.6 Kd	654 12.5 En	674 8.0 En	689 8.9 Pt	581 6.1 Kd
720[12.0 Gy	563 5.5 Kd	657 12.0 En	688 7.7 L	691 8.5 Jo	590 5.5 Kd
	565 5.4 Kd	657 12.1 Sl		695 8.6 Jo	611 5.8 Kd
	568 5.6 Kd	674 12.5 Sl		696 8.8 Ah	622 5.8 Kd

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J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
χ CYG	Z CYG	R SGE	U CYG	Y AQR	TW CYG
194632	195849	200916	201647	*203905*	210129
625 5.7 Kd	689 11.7 Pt	691 10.5 Jo	688 7.7 Jo	676 9.8 Mp	685 14.0 L
637 6.1 Kd	689 11.9 L	695 10.4 Jo	689 7.8 Pt	681 9.5 Jo	X CAP
642 6.1 Kd	S TEL	703 10.1 Jo	690 7.6 GD	686 9.6 Jo	*210221*
646 6.2 Kd	*195855*	RS CYG	690 8.5 Mn	688 9.6 Jo	660[12.1 En
652 6.3 Kd	657[12.6 En	200938	691 7.7 Jo	689 9.6 Pt	676[12.4 Bl
653 6.6 Kd	675 13.1 Bl	677 7.3 Jo	691 9.3 Mn	T DEL	RS AQR
655 6.7 Kd	SY AQL	684 7.2 Jo	692 9.2 Sf	204016	*210504*
677 7.0 Jo	200212	686 7.4 Cy	695 7.7 Jo	689 9.5 Pt	688 11.9 L
678 7.3 Jo	689 10.5 Pt	689 7.2 Pt	702 8.8 Mn	690 9.5 L	698 11.9 L
679 8.0 Kd	691 10.1 L	690 7.7 GD	702 8.2 Wd	V AQR	715 11.6 Pt
680 8.0 Kd	693 10.2 B	690 7.5 L	703 8.8 Sf	204102	Z CAP
681 8.0 Kd	S CYG	691 7.1 Jo	703 7.8 Jo	688 8.7 L	*210516*
681 7.7 Jo	200357	691 7.6 Cy	703 8.5 Mc	689 9.5 Pt	688 13.0 L
682 8.0 Kd	678 8.9 Jo	695 7.1 Jo	705 7.8 Jo	698 8.8 L	R EQU
684 8.0 Jo	681 9.9 Gy	702 8.4 Wd	706 7.9 Wd	W AQR	210812
686 8.3 Ah	683 9.9 GC	703 7.2 Jo	707 8.3 Mc	*204104*	683[12.9 Mp
688 8.2 Jo	684 9.0 Jo	703 7.5 Cy	709 8.2 Mc	688 13.5 L	686 14.1 L
689 8.0 Pt	688 9.4 Jo	705 7.2 Jo	U MIC	U CAP	T CEP
691 8.4 Jo	689 10.0 Pt	705 7.5 Cy	*202240*	*204215*	210868
692 9.2 Kd	691 10.9 GC	706 8.0 Wd	675[13.0 Bl	675[13.1 Bl	677 6.7 Jo
692 8.1 Bg	696 9.5 Jo	707 7.3 Sh	Z DEL	V DEL	678 6.9 Mn
695 8.6 Jo	703 9.8 Jo	720 7.8 Cy	202817	204318	681 6.6 Gy
696 8.9 Ah	R CAP	732 7.8 Cy	690 14.3 L	704 13.8 B	684 6.4 Jo
701 8.5 Bg	*200514*	R DEL	ST CYG	706 13.6 B	684 6.8 Mn
702 9.1 Wd	688 11.8 L	201008	202954	T AQR	686 6.6 Ah
703 8.6 Jo	689 11.8 Pt	651 8.7 Ko	683 13.3 GC	*204405*	690 6.8 Mn
705 8.7 Jo	S AQL	687 9.8 Th	686 13.6 B	676 10.9 Mp	690 6.7 Sh
706 9.4 Wd	200715a	689 9.3 Pt	689 13.6 Pt	679 10.9 Mn	691 6.7 Wd
707 9.3 Th	678 9.4 Jo	690 9.6 L	690 14.0 L	681 11.5 Jo	692 6.2 Th
710 9.6 Me	689 9.5 Pt	691 9.2 Jo	691 13.3 GC	686 12.0 Jc	695 6.6 Sh
721 9.6 Bg	691 9.4 Jo	696 9.6 Jo	V VUL	689 11.5 Pt	696 6.6 Sh
S PAV	695 9.5 Jo	RT CAP	203226	RZ CYG	696 6.3 Ah
194659	698 9.6 Bg	*201121*	689 8.6 Pt	204846	699 6.5 Sh
657 8.4 En	703 9.6 Jo	561 7.5 Kd	R MIC	689 13.3 Pt	701 6.5 Sh
674 8.2 En	710 9.8 Me	597 7.5 Kd	*203429*	709 13.3 B	702 6.5 Sh
RR SGR	RW AQL	624 7.6 Kd	675 9.2 Bl	S IND	702 6.6 Me
194929	200715b	646 7.5 Kd	Y DEL	*204954*	702 6.5 Wd
657 12.8 En	678 9.2 Jo	682 7.4 Kd	203611	675 11.6 Bl	704 6.0 Jo
675 11.9 Bl	689 9.5 Pt	689 6.4 Pt	X DEL	704 6.5 Gy	
RU SGR	691 9.4 Jo	SX CYG	205017	705 6.5 Sh	
195142	695 9.3 Jo	201130	690 12.6 L	705 6.2 Mn	
657 12.5 En	703 9.5 Jo	691[12.3 Cy	681 9.7 Jo	R VUL	706 6.5 Sh
674 12.3 En	R TEL	RT SGR	684 9.7 Jo	205923a	706 6.5 Wd
675 12.6 Bl	*200747*	*201139*	689 10.2 Pt	681 12.5 Jo	707 6.5 Sh
RR AQL	675 13.5 Bl	675[12.7 Bl	695 9.6 Jo	684 12.0 Jo	710 6.5 Sh
195202	RU AQL	WX CYG	703 9.6 Jo	688 11.8 Jo	714 6.2 Pt
687 11.1 L	200812	201437b	705 9.7 B	691 11.7 Jo	720 6.5 Sh
689 11.7 Pt	691 14.3 L	686 12.9 Cy	V CYG	695 11.0 Jo	720 6.5 Gy
698 9.9 L	W CAP	689 12.0 Pt	203847	703 10.2 Jo	RR AQR
NOV CYG	*200822*	690 12.1 L	678 9.8 Mn	705 10.0 Jo	*210903*
195553	675[12.8 Bl	691 12.5 Cy	684 9.8 Mn	714 9.0 Pt	688 14.3 L
691[12.2 Pt	Z AQL	U CYG	689 9.5 Pt	V CAP	715 12.4 L
713[12.2 Pt	*200906*	201647	690 8.9 L	*210124*	X PEG
RR TEL	650 9.4 Hi	677 7.8 Jo	690 10.0 Mn	660 11.7 En	211614
195656	689 11.3 Pt	678 8.4 Mn	698 10.1 Mn	675 11.7 Bl	690 13.3 L
657[12.6 En	R SGE	680 9.3 Mn	703 10.5 Sf	688 13.7 L	714 10.4 Pt
	200916	684 7.8 Jo	705 9.6 B		
	678 10.6 Jo	684 8.4 Mn	705 9.9 Mn		

VARIABLE STAR OBSERVATIONS RECEIVED DURING JANUARY, 1932.

J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.	J.D.Est.Obs.
T CAP	S CEP	RZ PEG	RW PEG	ST AND	Z AQR
211615	213678	*220133b*	*225914*	*233335*	*234716*
676 11.5 Bl	702 7.5 Sh	705 12.5 B	690 9.5 L	677 10.0 Jo	624 8.5 Kd
688 12.1 L	705 7.5 Sh	T PEG	704 9.0 Jo	686 9.9 Jo	646 8.3 Kd
S MIC	706 9.3 Th	*220412*	R PEG	690 10.3 Bo	680 8.4 Kd
212030	710 7.5 Sh	685 13.8 L	230110	691 10.3 Bo	692 8.9 Kd
676 9.1 Bl	714 8.6 Pt	706 12.8 B	681 10.1 Gy	691 9.8 Cy	RR CAS
Y CAP	720 9.2 Cy	Y PEG	703 10.9 Sf	692 9.8 Th	235053
213814	720 7.6 Sh	*220613*	715 11.5 Pt	692 9.5 Jo	697 11.5 B
676[13.1 Bl	732 9.2 Cy	683 10.4 GC	V CAS	704 10.0 B	706 11.4 Bn
688 13.6 L	RU CYG	RS PEG	230759	706 9.4 Th	718 11.2 Bn
W CYG	213759	220714	686 8.8 Cy	709 9.8 Bo	V CET
213244	685 7.7 Ry	680 12.1 L	691 8.4 Cy	715 9.5 Pt	*235209*
527 6.0 Kd	687 7.5 Ry	683 11.7 GC	696 8.2 Ah	720 9.6 Bo	676[13.0 Bl
556 6.0 Kd	696 8.0 Ah	691 12.1 L	703 7.6 Jo	732 9.6 Cy	R CAS
561 6.1 Kd	707 8.3 Th	T GRU	704 8.0 B	R AQR	235350
563 6.1 Kd	714 8.0 Pt	*221038*	705 8.0 Sf	*233815*	678 10.4 Mn
568 6.0 Kd	RV CYG	674 10.0 En	715 7.8 Pt	561 7.7 Kd	681 11.9 Gy
573 6.2 Kd	213937	S GRU	720 7.6 Cy	571 7.8 Kd	697 10.7 B
590 6.3 Kd	715 6.3 Pt	*221048*	721 7.7 Sf	595 8.0 Kd	703 10.7 Jo
595 6.2 Kd	RR PEG	660 11.4 En	732 7.7 Cy	623 8.7 Kd	704 11.6 Gy
597 6.2 Kd	214024	673 12.0 En	W PEG	624 8.7 Kd	705 10.6 Jo
611 6.2 Kd	715 13.0 Pt	RV PEG	231425	646 8.6 Kd	720 11.4 Gy
622 6.4 Kd	R GRU	222129	680 12.1 L	652 8.7 Kd	Z PEG
625 6.5 Kd	*214247*	685 13.9 L	S PEG	656 8.7 Kd	235525
642 6.4 Kd	660 9.5 En	S LAC	231508	676 9.0 Bl	680 10.2 L
646 6.4 Kd	674 8.3 En	*222439*	680 10.0 L	677 8.8 Jo	681 10.6 Gy
652 6.6 Kd	675 8.2 Bl	680 12.7 L	685 9.7 Mp	678 9.1 Mn	692 10.1 L
679 6.6 Kd	V PEG	705 13.2 B	688 9.7 Jo	679 8.9 Kd	715 9.6 Pt
681 6.6 Kd	215605	715 12.5 Pt	691 9.7 L	679 8.8 Jo	W CET
686 6.5 L	680 8.7 L	R IND	706 9.1 Th	680 8.8 Kd	*235715*
690 6.4 Oy	683 8.6 GC	*222867*	715 8.8 Pt	680 8.9 L	595 8.6 Kd
692 6.6 Kd	691 9.1 L	674 9.5 En	732 8.3 Cy	681 8.7 Jo	623 9.2 Kd
698 6.5 L	715 10.2 Pt	676 10.0 Bl	V PHE	684 9.0 Mn	624 9.4 Kd
S CEP	U AQR	T TUC	*232746*	689 8.8 Mn	646 9.7 Kd
213678	688 12.3 L	*223462*	660 10.4 En	690 8.9 L	652 9.7 Kd
683 9.6 GC	*215717*	674 8.7 En	674 9.7 En	692 8.7 Kd	Y CAS
690 7.4 Sh	715 11.6 Pt	R LAC	Z AND	704 8.6 Jo	235855
691 9.1 Cy	RY PEG	223841	232848	715 8.2 Pt	685 13.2 L
692 9.5 Th	*220133a*	685 14.0 L	686 10.7 Cy	*233956*	SV AND
695 7.4 Sh	705 12.3 B	RW PEG	691 10.8 Cy	Z CAS	235939
696 7.4 Sh	RZ PEG	225914	715 10.8 Pt	686[12.8 Cy	715 9.4 Pt
699 7.4 Sh	*220133b*	680 10.3 L	721 10.9 Bg	691[13.1 Cy	
701 7.5 Sh	685 13.0 L		732 11.5 Cy		

RAPIDLY VARYING IRREGULAR VARIABLES.

Star J.D.	Est.Obs.	J.D.	Est.Obs.	Star J.D.	Est.Obs.	J.D.	Est.Obs.
005840 RX ANDROMEDAE—				060547 SS AURIGAE—			
6685.5	13.3 Ry	6702.6	11.6 Pt	6688.2	12.7 L	6704.5	14.0 B
6687.4	12.8 Ry	6708.6	13.6 Br	6689.3	13.0 L	6705.6	14.5 B
6687.7	12.6 Br	6714.7	11.3 Pt	6689.7	13.8 L	6709.6	14.5 B
6690.8	11.5 Pt	6715.5	11.3 Pt	6690.8	12.6 Pt	6713.9	11.6 Pt
6691.6	11.9 Pt	6718.6	13.0 Pt	6691.2	14.4 L	6714.7	11.8 Pt
6693.5	13.0 Ry			6692.6	12.6 Pt	6718.7	13.0 Pt
				6693.7	14.2 L	6720.7	12.5 Cy
060547 SS AURIGAE—				6694.7	14.3 L	6721.6	12.5 Cy
6680.3	10.8 L	6686.3	11.5 L	6695.3	12.5 L	6722.5	12.5 Cy
6680.7	10.9 L	6686.6	12.2 Cy	6698.6	11.0 Pt	6724.9	12.5 Cy
6685.3	11.0 L	6686.7	12.2 L	6702.6	12.5 Pt	6732.6	12.5 Cy
6685.7	11.5 L	6687.3	12.5 L	6703.5	11.2 Cy		

VARIABLE STAR OBSERVATIONS RECEIVED DURING JANUARY, 1932.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.
074922 U GEMINORUM—						
	6680.7	12.8	L	6713.9	13.3	Pt
	6685.7	14.0	L	6714.7	12.4	Pt
	6686.7	14.0	L	6715.5	12.4	Pt
	6689.7	13.8	L	6718.6	12.4	Pt
	6690.8	13.3	Pt	6720.8	14.3	Ma
	6691.1	13.3	Sl	6721.6	12.4	Cy
	6693.8	12.4	Pt	6727.9	13.4	Cy
	6694.7	14.0	L	6732.6	13.3	Cy
081473 Z CAMELOPARDALIS—						
	6680.3	11.8	L	6691.7	13.1	Hu
	6680.7	11.7	L	6692.2	13.0	L
	6685.3	12.5	L	6692.6	13.0	Pt
	6685.7	12.4	L	6693.7	12.8	L
	6686.3	12.8	L	6694.7	12.7	L
	6686.7	12.4	L	6695.3	12.7	L
	6687.3	13.0	L	6698.2	10.9	L
	6688.2	13.0	L	6698.6	10.4	Pt
	6689.3	12.8	L	6702.6	11.4	Pt
	6689.7	12.6	L	6713.9	13.3	Pt
	6690.2	12.9	L	6714.7	13.1	Pt
	6690.7	12.8	L	6715.5	13.5	Pt
	6690.8	13.3	Pt	6718.6	10.6	Pt
	6691.2	13.0	L	6721.5	11.2	Bg
	6691.6	12.5	Pt			
094512 X LEONIS—						
	6713.9	13.0	Pt			
202946 SZ CYGNI—						
	6689.6	9.1	Pt	6698.6	9.1	Pt
	6690.8	9.1	Pt	6702.6	8.8	Pt
	6691.6	9.2	Pt	6714.7	9.2	Pt
	6692.6	9.2	Pt	6715.5	8.8	Pt
	6694.6	9.7	Pt	6718.6	8.9	Pt
213843 SS CYGNI—						
	6677.6	10.7	Jo	6677.6	10.0	Bc
	6678.6	11.0	Bc	6694.6	11.7	Pt
	6678.6	11.0	Jo	6695.3	11.8	L
	6679.6	11.0	Jo	6695.5	11.9	B
	6680.3	11.5	L	6695.6	12.0	Jo
	6681.6	11.5	Jo	6696.6	11.8	Jo
	6683.2	11.9	Ah	6697.5	11.9	B
	6683.6	11.9	Bc	6698.2	11.9	L
	6683.6	11.6	GC	6698.6	11.5	Pt
	6684.6	12.0	Jo	6699.6	11.8	Jo
	6685.3	12.1	L	6702.5	11.9	Cy
	6686.2	12.0	Ah	6702.5	11.5	Wd
	6686.3	11.8	L	6702.6	11.7	Pt
	6686.5	11.5	Cy	6703.5	11.7	Sf
	6687.7	11.6	Br	6703.6	11.7	Jo
	6688.2	11.9	L	6704.5	11.6	B
	6688.6	12.0	Jo	6705.5	11.7	Sf
	6689.3	11.8	L	6705.6	11.7	Jo
	6690.3	11.8	L	6705.6	11.1	Cy
	6691.5	11.6	GC	6706.5	11.5	Wd
	6690.6	11.7	Pt	6708.6	11.9	Br
	6691.2	11.8	L	6710.5	11.8	Mc
	6691.5	11.3	Cy	6713.9	11.7	Pt
	6691.6	11.7	Jo	6714.7	11.7	Pt
	6691.6	11.9	Bc	6715.5	11.7	Pt
	6691.6	11.6	Pt	6718.6	11.7	Pt
	6692.2	11.8	L	6720.5	11.2	Cy
	6692.5	11.6	Cy	6721.5	11.7	Bg
	6692.6	12.0	Bc	6721.6	11.2	Cy
	6692.6	11.7	Pt	6722.5	11.2	Cy
	6693.5	11.5	B	6726.5	9.4	Jo
	6693.6	12.0	Bc	6729.5	8.6	Jo
	6693.6	12.0	Bf	6731.5	8.5	Jo
	6693.6	11.7	Cy	6732.5	8.1	Cy
	6694.6	11.9	Cy	6735.6	8.6	Jo

SUMMARY OF OBSERVATIONS FOR JANUARY, 1932.

Observer	Initial	Vars.	Observations	Observer	Initial	Vars.	Observations
Ahnert	Ah	16	22	Kanda	Kd	22	157
Allen, P. R.	Al	5	5	Kohman	Ko	9	14
Baldwin	Bl	69	75	Lacchini	L	153	252
Bigelow	Bw	5	5	Marsh	Ma	26	26
Boutell	Bo	10	25	McLeod	Mc	9	19
Bouton	B	38	48	McPherson	Mp	9	9
Brocchi	Br	6	8	Meek	Me	6	7
Brown, A. N.	Bn	4	8	Mennella	Mn	43	58
Buckstaff, E.	Bf	2	5	McQueen	Mc	2	4
Buckstaff, R.N.	Bc	5	16	O'Byrne	Oy	5	6
Bunting	Bg	7	10	Peltier	Pt	173	241
Campbell	C	3	3	Popkavich	Pk	4	4
Cilley	Cy	25	85	deRoy	Ry	5	10
Ensor	En	47	75	Shinkfield	Sl	23	50
Jones	Jo	78	336	Smith, F. W.	Sf	17	27
Georgetown	GC	8	11	Smith, L.	Sh	6	27
Godfrey Club	GD	4	4	Theile	Th	13	19
Gregory	Gy	30	43	Webb	Wd	16	35
Houston	Hu	6	6	Whitney	Wy	5	7
Hildom, A.	Hi	7	10				
Hildom, L.	Hl	6	6	Totals		40	377	1778

Sagittarii appears to be slowly but surely headed for maximum, having spent more than a year at or near minimum.

Observers, especially those with the larger size instruments, are urged to pay particular attention to such irregular variables as RX Andromedae, Z Camelop, X Leonis, T Orionis, and RR Tauri. Only by securing practically daily observations of these stars can we hope to learn more definite facts concerning them.

LEON CAMPBELL, Recorder.

February 10, 1932.

Notes from Amateurs

The Enigma of Astronomy: Will It be Answered?

This is an age of wonders. Let us turn to one particular branch of human achievement for an example. Let us compare the modern astronomical observatory and its instruments with the most elaborate astrolabe of Tycho Brahe's day.

Housed beneath the huge dome we find the great telescope on its equatorial mounting, following smoothly and accurately the star on its celestial path. Cameras meanwhile labor unceasingly for hours at a time, recording for future reference enormous numbers of images of stars and nebulae. The transit instrument notes the passage of a given star across the meridian and the correct time is thereby ascertained. The spectroscope, with the aid of the camera, produces for the astrophysicist a plate of beautiful colors; close scrutiny of this spectrum and its dark lines reveals the chemical composition of the distant star. Manifold are the complexities of research available due to these and other delicate mechanisms. Thus the work of the modern observatory compares in scope with the angle measurements of Brahe.

Yet with these wonders at his command, man today has still occasion to wonder and speculate! For all of these instruments, man still can but theorize regarding life on other worlds. A great mass of detail has resulted from these modern researches—yet these facts do not point the stirring question to one definite conclusion. Voluminous books have been written by highly capable scientists who firmly asserted that there is life on other worlds. Voluminous books also have been written by equally great scientists whose expressed views are quite to the contrary. And the former even do not agree as to what planet is most probably the abode of life. Some favor Venus, while others can only contemplate Mars as capable of supporting life similar to ours.

What is one to believe? Is there no hope for the solution of this mystery?

It is admitted that telescopes have very nearly reached their maximum degree of perfection, for the atmosphere of our planet is an unsurmountable barrier to greater magnifying powers. Yet there is a hope. Let us begin by constructing a simple picture in order to see clearly what that hope is.

Let us imagine a pair of huge, though delicate, scales. At one end we place the ponderous, weighty, question of life on other worlds. Immediately it falls to the ground amidst the dark shadows of uncertainty, leaving the other end high in the air. Now we place the instruments of bygone days on this uplifted end and watch the result. Puny, indeed, are these instruments and the enigma scarcely budges. Next we deposit a model modern observatory beside the quadrant and the astrolabe. Ah! The scales commence to move! Up comes the enigma until it is on a level with the aggregated instruments. But it will go no farther. There

is an extended wavering, see-saw effect but the instruments are unable to definitely force the enigma to its greatest possible height and enlightment. We think deeply. Cannot we devote our minds and energies to devise some radical instrument that will furnish us with the last necessary amount of weight?

Ah! If we only had a rocket ship—a navigator of space! Vividly we imagine the unique instrument added to our forces and the up, up, upward rise of the enigma until it reaches the enlightened top.

That picture before us, we see clearly the only solution to the engaging problem. To one who has hope and faith in the ingenuity of mankind there is no alternative except to believe that eventually the problem will be solved by the mind of man. Back in the dawn of mankind if a cave dweller in the course of his explorations came to the banks of a strange river he soon began to wonder what was on the other side. Eventually he crossed over and satisfied his curiosity. Man today wonders what is on the planets across the vast river of space. Eventually he will cross over and find out. As the first bold cave man in all probability paid dearly for his lack of facts concerning the river—perhaps he was drowned or was devoured by some strange denizen of the deep—so, too, the first space ship may become a hurtling coffin soon after its start into the unknown. But others will profit by the experiment and succeeding ships most probably will reach their destination with living crews.

It is almost beyond the power of words to express the possibilities and revelations of any such a flight. Yet, in an editorial of a prominent newspaper there recently appeared the following—"What rewards such a visitation might yield to science is conjectural" and "For the layman sightseeing on the moon might prove tame, and the amusement facilities would necessarily be restricted." As if the primary, driving, impulse to gain the moon or any other body was actuated by a desire for mere amusement! And as for scientific results of such a trip being classified as "conjectural," that is naught but sheer irrationality. True, a trip to the moon may not solve the enigma of life on other worlds besides our own. The moon today is dead and cold. Yet there may be remains of ancient civilizations on our satellite—perhaps beneath its surface. Besides, the puzzling streaks radiating from Tycho, the sun's corona, a possible intra-Mercurial planet, the Milky Way—all these and many other mysteries could be best studied from the surface of the lunar orb. In any case, once the moon has been achieved Mars and Venus are easily next in order.

Inter-planetary travel, the "dream of the engineer, the physicist, and the astronomer"—may it come true soon! Let us hope and strive for the not far distant day when this glorious dream becomes an equally glorious reality.

10 Hudson Street, Easthampton, Massachusetts. FRANK EARUS.

Water

Among the many discussions relative to the formation of systems and worlds, it appears that few have hypothesized directly upon the question concerning the requisite conditions which have resulted in the existence of such a large quantity of water upon the earth.

When we consider that approximately three-quarters of the visible portion of our globe consists of this liquid and that, in its natural or associate forms, it is found on many members of our solar system, we may be prompted to inquire of its origin, of its part in the early formation of the sun's family, and of its possible destiny on the earth.

Astro-chemistry informs us that the elements hydrogen and oxygen are abundant upon the surface of our central luminary. Cosmology informs us that the earth and other members of the solar system were, in the far distant past, a part of that fiery orb. Thus, we are led to assume that, even in their gaseous state, all members of our system contained large quantities of these elements proportional to their initial size.

Without entering into the depths of theory concerning the formation of our earth, it would appear that, in its concentration and rotary motion, the mass became more and more heated; this heat intensifying to a maximum as the mass attained a certain centralization. During this process many elements combined, the heavier substances strongly attracted to the central mass, while the lighter, including water vapor, ascended to form the atmosphere. The vapor extended above the intensely heated mass to a height permissible by the temperature, density, and extent of the then rarified gases. The upper portions of water vapor coming in contact with the frigidity of high altitudes would immediately condense into rain, which would precipitate down to a region of intense heat, or upon the hot mass, where it would vaporize and again ascend. This action possibly continued for an indeterminate number of years. The density and extent of water vapor then encircling the earth would be governed by the extent, temperature, and pressure of the atmosphere, which in turn would be regulated by the quantity of gases which ascended, and the volume, temperature, and attraction of the central mass. Now, with a dense blanket of vapors the radiation of heat from the planet would be considerably retarded. Cooling would advance slowly, lengthening the period of this process. Yet radiation persisted and at a fixed lower temperature a portion of the continuous precipitation remained upon the boiling surface. Uninterrupted cooling of both atmosphere and mass resulted in additional condensation and an increased quantity of precipitation remained upon the earth. The mass and atmosphere continued to cool until the heat from the sun became the chief cause of evaporation and the quantity of water upon the earth reached approximately what we see today.

Sufficient earth-heat and sun-heat still prevail in and around our planet as yet to prevent the entire descent of water vapor. But, may there not come a time when the earth shall have entirely cooled and our waters seep through the crust to occupy the space made available by the escape of gases and molten rock? Could this continue until the surface is as arid as that of our satellite—the moon? Or will the waters not completely vanish and the sun, by its heat, and the altitudes, by their frigidity, create a balance between evaporation and condensation—until the solar fires diminish and we find our waters turned to ice?

The reasonableness of these assumptions is apparent, as we find that naturally or chemically such actions are always produced. Furthermore, we may look to other members of our system and observe similar conditions existing and similar changes taking place.

Assuming that all the planets were torn or thrown from the sun at the same time, it appears obvious that the greater the quantity of matter, the more time would be required for it to cool. At this point it may be well to mention that for every planet there are some gases which must escape. The initial rise in temperature increases molecular activity. Gravity tends to retain all molecules, yet under certain conditions, depending on the planet's volume, force of gravity, and temperature, the most active molecules escape into space—lost forever to the planet.

Omitting the outermost planets because of rather indefinite information, we turn our attention to Jupiter and Saturn. These planets, of enormous size, have not sufficiently cooled and we find a difference of rotation at various distances from the equator. Scientists interpret this as a result of a liquid surface, or, as a result of dense clouds kept aloft by the heat from below.

Upon Mars we find conditions quite different. Here the surface is perceptible. Its rotation is constant. Due to its small size, cooling has advanced. Gravity is relatively feeble, hence much of its atmosphere has been lost to space. Still upon its surface we observe snow caps and an occasional cloud. The green tinge, near the equator, is said to be vegetation regions. Water in some form is undoubtedly present.

Venus exhibits a surface covered with dense clouds, through which no markings can be distinguished. Its period of rotation remains unproven. Its size and force of gravity is approximately that of our earth. We may assume the quantity of water there to be nearly the same as upon the earth. Can its proximity to the sun retard its cooling? Is the sun's heat sufficient to keep its surface and atmospheric temperatures requisite for such vapors? Or, has its surface cooled and does the sun alone heat its atmosphere sufficiently to retain such quantities of water vapor?

Nearest to the sun is Mercury. The smallest planet in our system, whose force of gravity is less than that of Mars. Most of the lighter gases must have escaped. The nearness of the sun makes Mercury extremely difficult to observe. Yet it is believed, though not definitely proven, that it presents the same face continually towards the sun. If so, the perpetual dark side must be cold enough to freeze air. Should there ever have been water upon the planet then all on the bright side must have been vaporized by the terrific sun-heat and carried to the dark side where it would congeal into permanent ice.

The destiny of our waters may or may not be governed by conditions found upon other members of our system. Yet a summary of these may lead us to a possible solution.

A sufficient increase of temperature would vaporize the entire volume. The retardation of the earth's axial rotation until the day is equal to the year would result in all our water evaporating from the bright side and congealing into ice upon the dark side. The absorption of water by the earth would soon render the surface as arid as that of the moon. The death of the sun would transform our waters to ice. Or—will some unforeseen celestial catastrophe answer, in its own manner, this rather involved question?

JOHN M. CROTHERS.

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Amateur Telescope Makers of Chicago

(February Meeting)

Fred Ayres, Astronomical chairman for February, introduced Mr. Purcell who discussed Cosmic Rays. President McCord in the short business session detailed the new round table method of conducting the society. The proposed plan is to have the leadership change each month.

The Technical Session, James E. Crites, Jr., Chairman, had for the speaker Dr. S. Jacobsohn of Gaertner Scientific, who discussed eyepieces and refractor lens designs. (We visited the factory of Gaertner Scientific the following Saturday, and saw their very complete lens grinding and polishing equipment in operation.)

Two mirrors, free of strain as shown by polarized light, were displayed—a 5-inch by Buttles and a 10-inch by McCord. Buttles has ground over twenty mirror blanks to six-foot focal length by using a machine he is developing. He is using 1½-inch thick clear glass to overcome errors introduced by local springiness of thin glass. Glass is first analyzed by polarized light to make sure of freedom from internal strains. This and the use of thick glass is expected to overcome the difficulties of astigmatism, a common trouble heretofore.

McDonough has started an 8-inch mirror. Robert Weaver, 2101 S. 7th Avenue, Maywood, is making three 5-inch optical flats, and has put in a motor driven spindle to make low power, wide field eyepieces. His first 2½-inch focus Ramsden has an apparent field of over 45° making a good substitute for a finder telescope.

Correspondence is invited by other amateurs. Address 10728 S. Artesian Avenue, Chicago, Illinois.

G. E. McCord, *President;* L. I. Buttles, *Publicity.*

General Notes

Dr. William Wallace Campbell, president emeritus of the University of California, for many years the director of the Lick Observatory, now the president of the National Academy of Sciences, has recently received the honorary degree of Doctor of Science from the University of Chicago.

General Gustave Ferrié, a pioneer in the development of wireless telegraphy for military purposes, died in Paris on February 16 at the age of sixty-three. General Ferrié was present when Marconi's famous experiments were carried on between France and England in 1899. As chief of the Eiffel Tower Wireless Station and general inspector of the French military telegraph he was a leader in all radio and photo-electric experiments for the last two decades.

General Ferrié was a faithful attendant at the meetings of the International Astronomical Union and of the Central Council of Scientific Unions. Last summer he was elected First Vice-President of the latter and was the President of an important commission for the correlation of radio and solar phenomena. He was also in charge of the World-Longitude Campaign carried out a few years ago.

Charles Sheldon Hastings, professor emeritus of Yale University, an authority on optics and optical instruments, died in Greenwich, Connecticut, on Saturday, January 30, 1932. He was born on November 27, 1848. He prepared for college at the Hartford High School and in 1870 was graduated from the Sheffield Scientific School at Yale. For the next three years he took graduate courses at the school. From 1871 to 1873 he was instructor in physics there. He spent the next two years in research at the University of Heidelberg and Berlin and a third year at the Sorbonne in Paris. In 1876 he became Associate Professor of Physics at Johns Hopkins University. In 1884 he was appointed Professor of Physics at Yale, where he remained until his retirement in 1915. Professor Hastings was consultant for the Brashear Company and for its successor, the McDowell Company, throughout practically their whole existence. He has been responsible for all the mathematical designs of the telescopes and other apparatus for which these two companies are famous. Among his largest pieces of optical design are the 30-inch photographic refractor at Allegheny, the 26-inch Yale

photographic refractor at Johannesburg, and the 72-inch reflector at Victoria. Almost all the larger visual refractors in this country are provided with correcting lenses of his design and he also played an important part in the early history of the spectroscope and the spectrograph in designing suitable lenses for the collimators and the cameras. He was an expert optician himself; he had made several small objectives and other optical apparatus, principally to test the validity of some of his calculations.

The McMath-Hulbert Observatory, located at Lake Angelus near Pontiac, Michigan, recently has been deeded by its founders to the University of Michigan. This deed of gift was accepted by the Regents on January 29, 1932, and this institution thus becomes a branch of the Observatory of the University of Michigan. Another branch, the Lamont-Hussey Observatory, is located at Bloemfontein, South Africa, given by Mr. Roscoe Lamont to carry to the southern skies the researches of former Director William J. Hussey on double stars. The builders of the McMath-Hulbert Observatory are Francis C. McMath, consulting engineer, Detroit, Robert R. McMath, manufacturer, Detroit, and Henry S. Hulbert, Senior Judge of Probate, Detroit. They have developed a successful telechron driving clock for their telescope, and lately have been making moving pictures of certain celestial phenomena, such as the change in the moon's phases, the rotation of Jupiter, and others.

The House of Rudolph Fuess, established in 1865 in Berlin, has recently opened an American office at 245 West 55th Street, New York City. This firm was so successful and became so well known by the high quality of its product that, five years after it was started, it was obliged to move into larger quarters. In 1892, because of continued growth, the headquarters of the firm were moved to Steglitz, a suburb of Berlin, where there was opportunity for adequate expansion.

This house is noted for its instruments of precision in seven departments, namely: A. Measuring instruments for air pressure, temperature, and humidity, and testing apparatus and open air housings; B. Measuring instruments for wind, rainfall, evaporation, radiation, and sight; C. Thermo-control instruments for the measurement of flow, pressure, and vacuum; D. Microscopes and instruments for general optical observation and material research; E. Spectroscopic apparatus, goniometers, refractometers, and special instruments for crystal-optical determination; F. Apparatus for the measurement of water levels and quantities; G. Special apparatus made to specified requirements.

Book Reviews

The Adventure of Mankind, by Eugen Georg, translated from the German by Robert Bek-Gran. (E. P. Dutton and Co., Inc., 286-302 Fourth Avenue, New York City.)

This volume was issued during the latter part of last year. The exact time of its appearance is of little relative importance because of the almost timelessness of its presentation. Its scope is tremendous. The span of recorded history is merely an incident in the eons which are encompassed. In imagination the reader is transported into the past even antedating the formation of the earth and of the

entire solar system. In a sketchy and rather free manner the author accounts for the solar system along lines of thought somewhat similar to the now generally accepted ones, but with some modifications. The mass now comprising the solar system was once a unit, in the rôle of a secondary body revolving about a much greater primary. At length the secondary fell into the body of the primary. In the course of time it was shot out again with explosive violence of incomprehensible proportions and started on its tremendous journey Hercules-ward, as we have recently discovered.

Ultimately simple life appeared which developed into more and more complex life and finally into its highest form, mankind. But between this early mankind and the present there intervened many vicissitudes. Catastrophes, such as the crashing down of moons upon the earth, world-wide floods submerging entire continents, ice masses sweeping everything before them, appearance out of the deeps of new land areas befell civilization after civilization. The latest one to disappear was that of the island Atlantis, whose location is not certainly known, but traces of the culture of the Atlanteans are noted in many aspects of recorded history. And the final catastrophe is yet to come. As far as the earth is concerned it will take place in this manner. "All will finally disappear in the maw of the sun, as that time comes at last when the earth, swollen with Mars and the moon, swinging in a giddy spiral ever nearer to the sun, makes its plunge into the gigantic flaming abyss!" p. 141.

The author is exceedingly daring in the finality with which he presents his hypotheses, some quite new. The reader may not be ready to follow the writer into all of his discussions which sometimes are carried into the hazy regions of mysticism. One cannot but admire the power of imagination and the marvelous grasp of history which are manifested in the writing of such a volume. The three hundred twenty-five pages are solidly packed with matter very stimulating to the thoughtful reader. It surely creates in one an enlarged view of mankind—its past and its future.

The translation is done with finish and elegance. The translator evidently caught the thought of the writer very thoroughly, and has presented it very lucidly in the English version.

Contributions from the Mount Wilson Observatory.—Copies of the following have recently been received.

No. 425. The Spectrohelioscope and its Work, Part III, by George E. Hale.
426. Apparent Velocity-Shifts in the Spectra of Faint Nebulae, by Milton L. Humason.
427. The Velocity-Distance Relation Among Extra-Galactic Nebulae, by Edwin Hubble and Milton L. Humason.
428. Effect of Space Absorption on the Calculated Distribution of Stars, by Frederick H. Seares.
429. The Spectroscopic Orbit of RT Lacertae, by Alfred H. Joy.
430. The Distribution of Absolute Magnitudes Among F and G Stars Brighter than the Sixth Apparent Magnitude as Determined from Parallactic and Peculiar Velocities, by Gustaf Stromberg.
431. The Potsdam Scale of Visual Magnitudes, by Frederick H. Seares.
432. A Plane-Grating Spectrograph for the Red and Infra-Red Regions of Stellar Spectra, by Paul W. Merrill.
433. Orbital Elements of the Spectroscopic Binaries H.D. 73619, 75767, 206546, and 214686, by Roscoe F. Sanford.
434. The Spectrohelioscope and its Work, Part IV, by George E. Hale.
435. The Photographic Determination of Stellar Parallaxes with the 60- and 100-inch Reflectors, by Adriaan van Maanen.